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AIRCRAFT GUN ICING EVALUATION

Max L. Coppock

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TECHNICAL REPORT

U.S. ARMY ARMAMENT COMMAND

AIRCRAFT & AIR DEFENSE WEAPONS SYSTEMS DIRECTORATE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discusses the results of icing tests conducted on the M28A1 Turret, the 7.62mm, M134 Gun, the 40mm, M129 Grenade Launcher and the 20mm, M195 Gun. The results indicate that all of the weapons can be fired without catastrophic damage after accumulating as much as 1 1/4 inches ice on the muzzle. The use of gas deflectors and/or flash suppressors allow the weapons to be fired without any damage occuring from ice accumulation of up to 1 1/4 inches. The turret suffered only minor limitations of movement, when coated

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with 1 1/4 inches of ice. The extreme limits of elevation could not be attained due to ice jamming the stops but about 85 percent of the excursion distance was operable. A build-up of over 3/8 inches of ice on one side of the turret will limit the azimuth movement in one direction only. A heavy ice build-up cannot pass the close gap between turret and aircraft fairing behind the turret. This situation can be prevented by pointing the guns into the wind causing the ice build-up to be on the front turret surface.

SUMMARY

Conclusions:

This report discusses the results of icing tests conducted on the M28A1 Turret, the 7.62mm, M134 Gun, the 40mm, M129 Grenade Launcher and the 20mm, M195 Gun. The results indicate that all of the weapons can be fired without catastrophic failure after accumulating as much as 1 1/4 inches of ice on the muzzle. The M134 Gun without flash suppressor will have a slight bore enlargement due to this type of firing. The M134 Gun and the M195 Gun when using gas deflectors or flash suppressors can be fired without any damage after accumulating as much as 1 1/4 inches of ice. The M129 Grenade Launcher can also be fired without damage with as much as a 1 1/4 inch ice accumulation. The turret operated in both elevation/depression and azimuth with only minor restrictions after being coated with 1 1/4 inches of ice. The full limits of elevation or depression could not be attained due to ice jamming into the stops. However, about 85 percent of the excursion distance was possible. The ice build-up on the turret was greatest on the area facing the wind. If this area of greatest ice build-up is between or near the guns, there is no problem in azimuth movement. However, if the area of greatest ice build-up is on one side of the turret and is greater than 3/8 inch thick, the iced area cannot be moved past the small opening between turret and aircraft fairing. Therefore, azimuth motion is limited in one direction.

One overall limitation that must be considered is the fact that these tests were conducted with a simulated wind of 13 knots. The results might be somewhat different at a higher wind velocity.

In the opinion of the test personnel, there is no danger of a barrel blowing up from being fired during icing conditions. This is limited to the weapons tested and thickness of ice applied during this test.

The relatively soft ogive of the inert 40mm M384 cartridge was not dented or damaged in any way when fired through barrels that were coated with 1 1/4 inches of ice. These cartridges were flattened somewhat on the nose when fired through the 1 1/2 inch and 2 inch ice plugs.

Recommendations:

The findings of this test should be confirmed by conducting aerial firing tests during icing conditions in which the turret and weapon are faced into the wind.

A gas deflector or flash suppressor should be used on all weapons smaller than 40mm during icing conditions when the total accumulation can attain 1 1/4 inches.

The use of a de-icing cream or substance is not required on the M28A1 turret or weapons. The cream used for ice prevention in these tests may have an application on other helicopter surfaces. This aspect should be explored further.

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1. Introduction:

This study was conducted under Project No. 1F264202 D133.32, Aircraft Gun Type Weapons/Aircraft Gun Icing Evaluation.

USA TRADOC has expressed support of the requirement for an anti-deicing capability for the present fleet of Army helicopters as well as future generation helicopters (USA TRADOC letter ATCD-CM-CAS dated 16 April 1974, Subject: Draft Amendment to the Catalog of Approved Requirements Documents (CARDS). A draft Letter of Agreement (LOA) for the Operational Evaluation of an Advanced Ice Protection System for the UH-1 Helicopter has been prepared and was circulated for comments in July 1975. The QMDO for the R&D anti-icing program was established in August 1969. At a meeting held at Ft. Eustis, VA in June 1975, the User's position was voiced in favor of an anti-icing program.

The purpose of the Aircraft Gun Icing Evaluation Program was to determine problem areas and possible hazardous conditions created when operating a Cobra Helicopter Armament Subsystem coated with ice.

Environmental tests are normally conducted on all weapons and armament subsystems. These tests include water testing, cold and frost testing and sometimes, icing tests. In all previous icing tests the gun barrels were capped or protected from the ice in some manner to prevent ice from forming in the barrels. The test described in this report is the first known effort to evaluate the effects of firing weapons which have ice in the gun barrels.

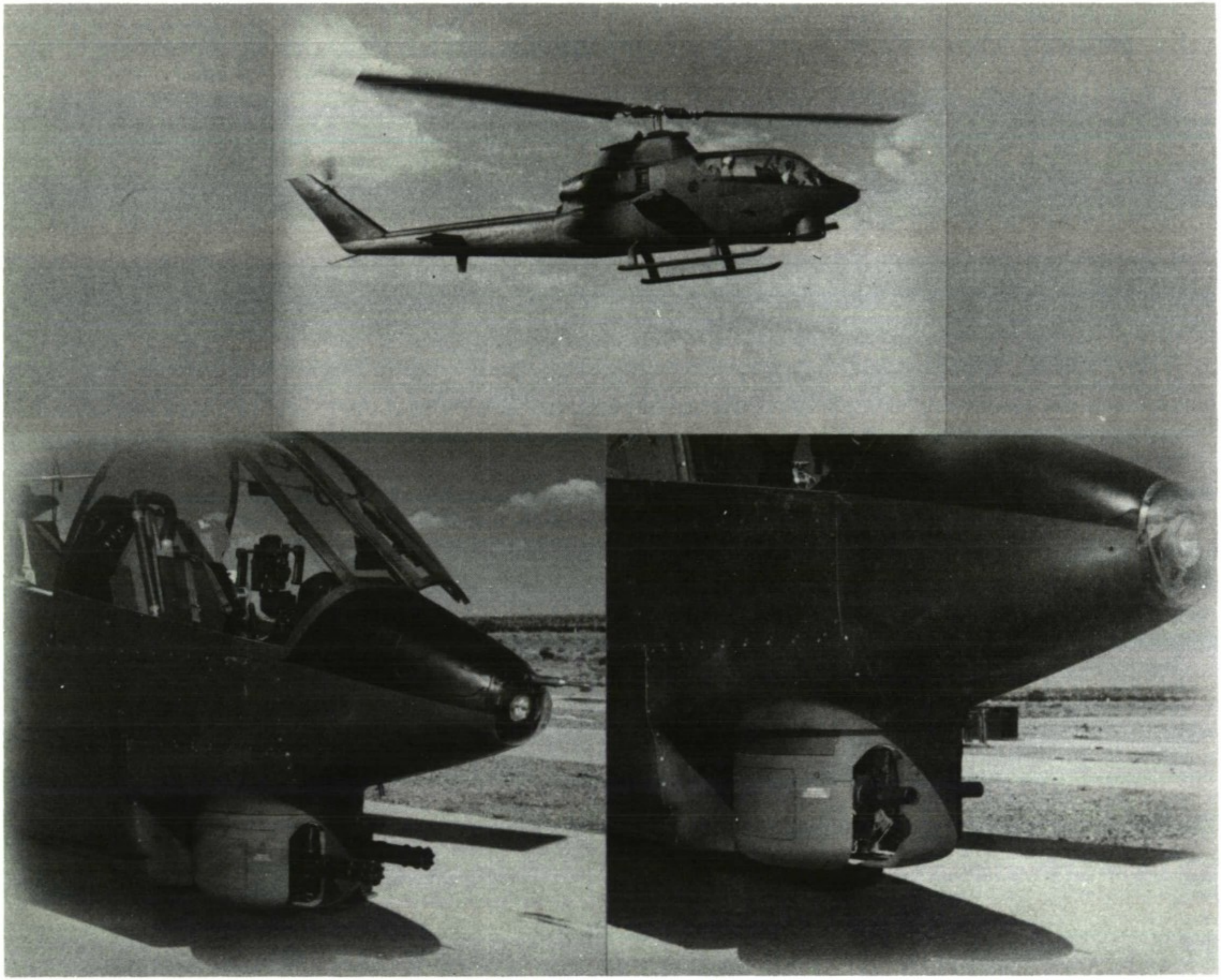

Fig. 1, M28A1 ARMAMENT SUBSYSTEM ON THE COBRA HELICOPTER

2. Main Report:

2.1 General.

Icing conditions have been divided into four categories, which are designated as: trace icing, light icing, moderate icing and heavy icing. These are defined as follows:

1. Trace icing: 0.5 inch thickness of ice forms on aircraft in distance of 60 miles, when traveling at 120 knots.

2. Light icing: 0.5 inch thickness of ice forms on aircraft in distance of 40 miles, when traveling at 120 knots.

3. Moderate icing: 0.5 inch thickness of ice forms on aircraft in distance of 20 miles, when traveling at 120 knots.

4. Heavy icing: 0.5 inch thickness of ice forms on aircraft in distance of 10 miles, when traveling at 120 knots.

TRADOC desires that the fleet of Army aircraft have the capability to operate in moderate icing conditions. The tests conducted in this evaluation were designed to simulate a situation at least as bad as heavy icing would produce.

The purpose of the test was to determine the effects of icing on Cobra Helicopter Armament. The M28 Armament Subsystem (Figure 1) was selected as the most representative Cobra Subsystem, since it has two weapons: the 7.62mm, M134 Machine Gun and the 40mm, M129 Grenade Launcher. The M134 represents small caliber, rapid firing, multi-barrel weapons. This gun was also used to show the effects of icing with and without a flash suppressor. The M129 represents single barrel, slow firing and relatively large caliber weapons (for aircraft). The M28A1 Turret is fully flexible in elevation and azimuth. The M195 Automatic Gun, mounted on a fixed test stand was also included in the test since it represented existing Cobra Armament (M35 Subsystem shown in Figure 2), as well as proposed future armament (Universal Turret Program). The M195 Gun has a 20mm bore, is multi-barrel, fires at moderate rate (750 shots per minute) and uses a gas deflector on the barrel muzzles.

The icing evaluation program was divided into eight phases as listed below:

Phase I, 7.62mm, Single Barrel Tests.

Phase II, 7.62mm M134 Gun, Clear Mode, Without Flash Suppressor.

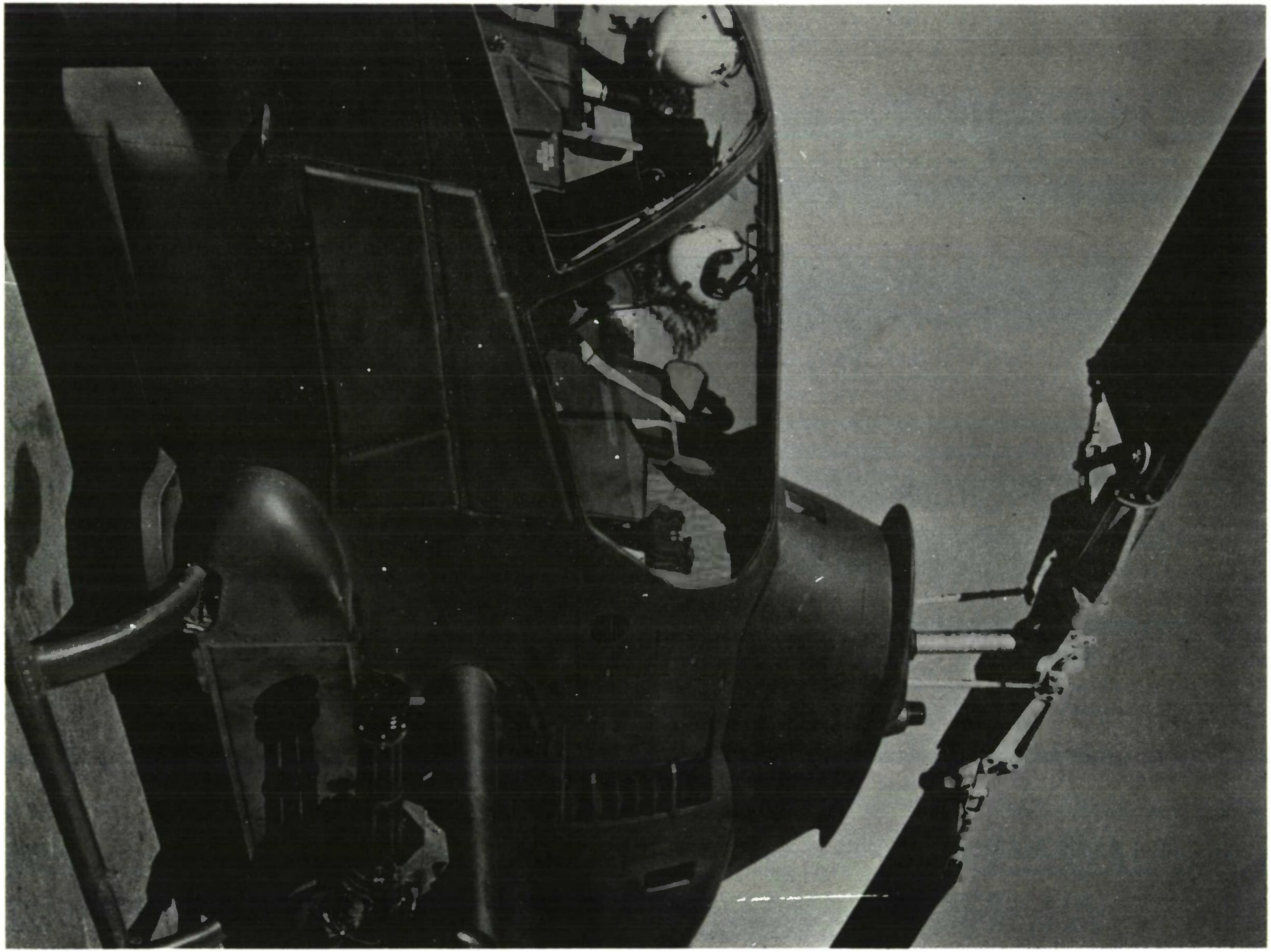

Fig. 2, M195 Gun/M35 SUBSYSTEM ON COBRA HELICOPTER

Phase III, 7.62mm, M134 Gun, Clear Mode, With Flash Suppressor.

Phase IV, 40mm, M129 Grenade Launcher.

Phase V, Turret Functioning.

Phase VI, 20mm, M195 Automatic Cannon.

Phase VII, Evaluation of Ice Prevention Methods.

Phase VIII, 40mm Barrel Test.

2.2 Test Equipment and Procedures.

The normal procedure for conducting tests was as follows:

a. Operate the turret or weapon at ambient temperature to be assured that it is in working condition.

b. Cold soak the test item overnight at 0°F.

c. Operate the system or weapon the following morning after cold soak to be sure the item still is in working condition.

d. Cold test item with ice.

e. Conduct test.

f. Dry out system or weapon in preparation for a repeat of the cycle.

The turret and weapons were cold soaked and coated with ice in the Rock Island Arsenal cold room. The weapons were then moved to an opening in the wall of this room, which allowed them to be fired into an adjacent test range. The cold room was held at approximately 0°F. This temperature is probably colder than would occur under natural icing conditions but it produced ice faster, which speeded up the testing process.

A garden spray type of nozzle was used to spray water onto turret and/or weapons. One water line and one air pressure line were attached to the nozzle. Air was supplied at 30 lbs. per square inch gauge (psig) pressure and the water was supplied at 57°F under a pressure of approximately 45 psig. The nozzle was pointed at mid-point to the front of the turret at a distance of about 24 inches from the turret. The nozzle was aimed directly at the muzzle of the M195 gun at about the same distance. The nozzle at times would freeze,

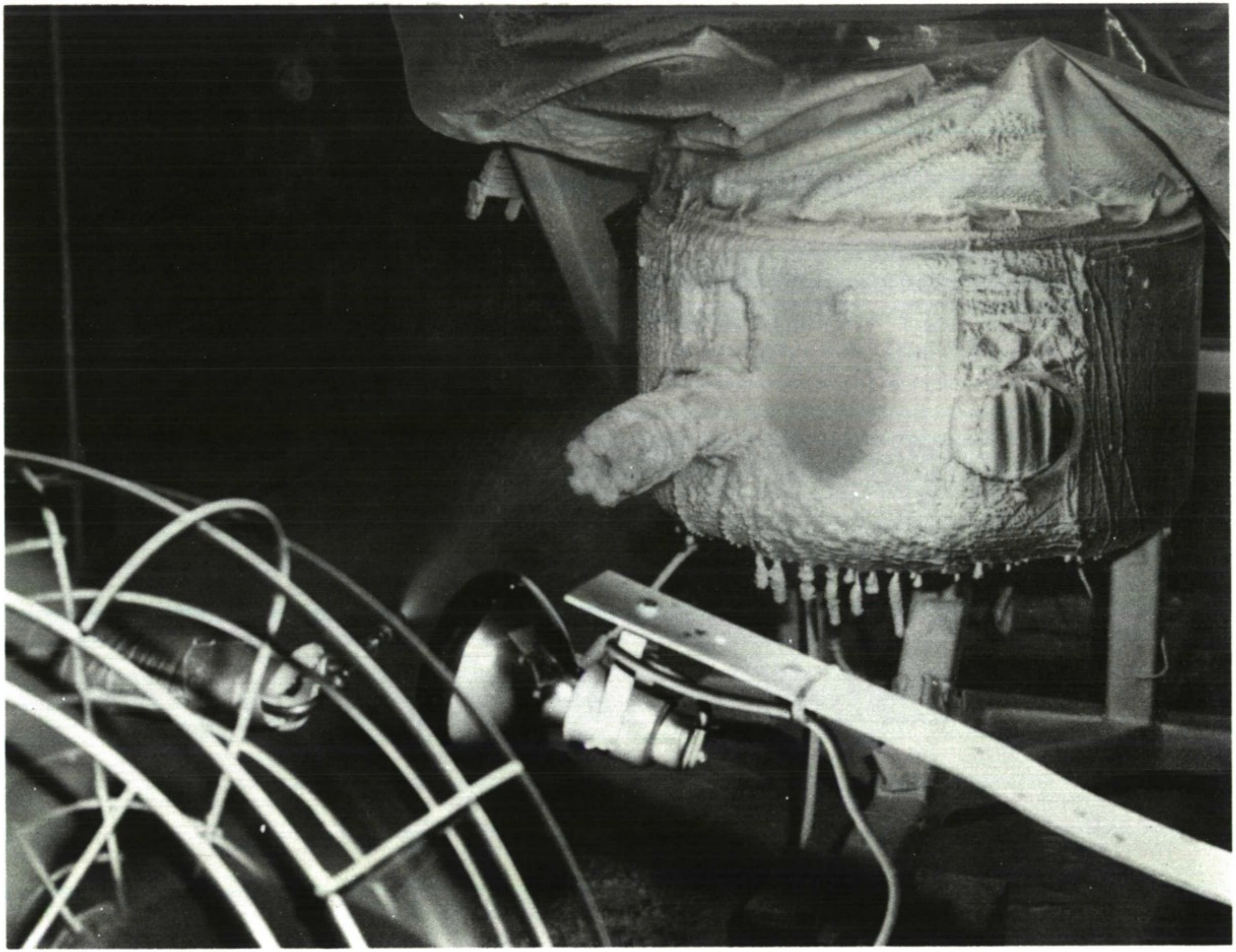

Fig. 3, SPRAYER WITH HEAT LAMP

therefore a heat lamp aimed at the nozzle was added to the test set-up to keep it operational (Figure 3). A metal scale was attached perpendicularly to the front of the turret and was used to determine the ice thickness on the turret or turret weapons (Figure 4).

2.3 Test Phases.

2.3.1 Phase I, 7.62mm Single Barrel Tests.

Eighteen individual 7.62mm barrels were used in this test. Varying amounts of water were poured into each barrel, frozen and then fired from a fixture (Figure 5). Six different quantities of water were used: 0.27 cubic centimeters (cc), 0.54cc, 0.82cc, 1.09cc, 1.64cc and 2.18cc. Three barrel positions were used during the water freezing procedure for each different quantity of water. In position no. 1, the barrel was positioned vertically with the muzzle pointed downward. The ice that formed in this position formed a flat faced plug in the barrel muzzle. In the second position, the muzzle was pointed downward, but at a 45° angle, during the freezing period. This created an ice wedge type of plug in the muzzle of each barrel. In the third position, a cartridge was inserted into the breech of each barrel and placed in a vertical position with the breech pointing downward. This froze the cartridge in place in the breech.

2.3.1.1 Phase I Test Results.

The data from this test is shown in Tables A-1, A-2, A-3 and A-4. Two barrels (Nos. 4 and 5) were used as control barrels. No. 4 was not fired and No. 5 was fired but without any ice in it. Measurements were taken on the outside diameter (O.D.) of all barrels at two places near the muzzle and at one position near the breech. The points selected for measurement were near the ice plugs and were the areas which were expected to be the most effected. Table A-2 shows those barrels which had an increase in O.D. measurement due to the firing. Barrel bulge first occurred with .54 cubic centimeters of ice (.456 inches deep in bore) in the muzzle. This increase in barrel O.D. (.011 inch) was noted at 11/16 inch from the muzzle. As the amount of ice increased, the amount of bulge increased and moved further back from the muzzle. With 1.09 cc the greatest bulge was observed at 1 1/4 inches from the muzzle. The amount of bulge at this point was a maximum of .030 inch for 1.09 cc of ice and did not increase for larger amounts of ice up through 2.18 cc. The bulge at the 11/16 inch point remained about the same as for .54 cc of ice. The shape of the surface of the ice plug (flat vs 45° angle) did not appear to make any difference. There was no apparent bulge in the barrel O.D. at the breech for any thickness of ice used in the breech (or muzzle ends). Pictures taken inside the bulged barrels adjacent to the areas plugged with ice

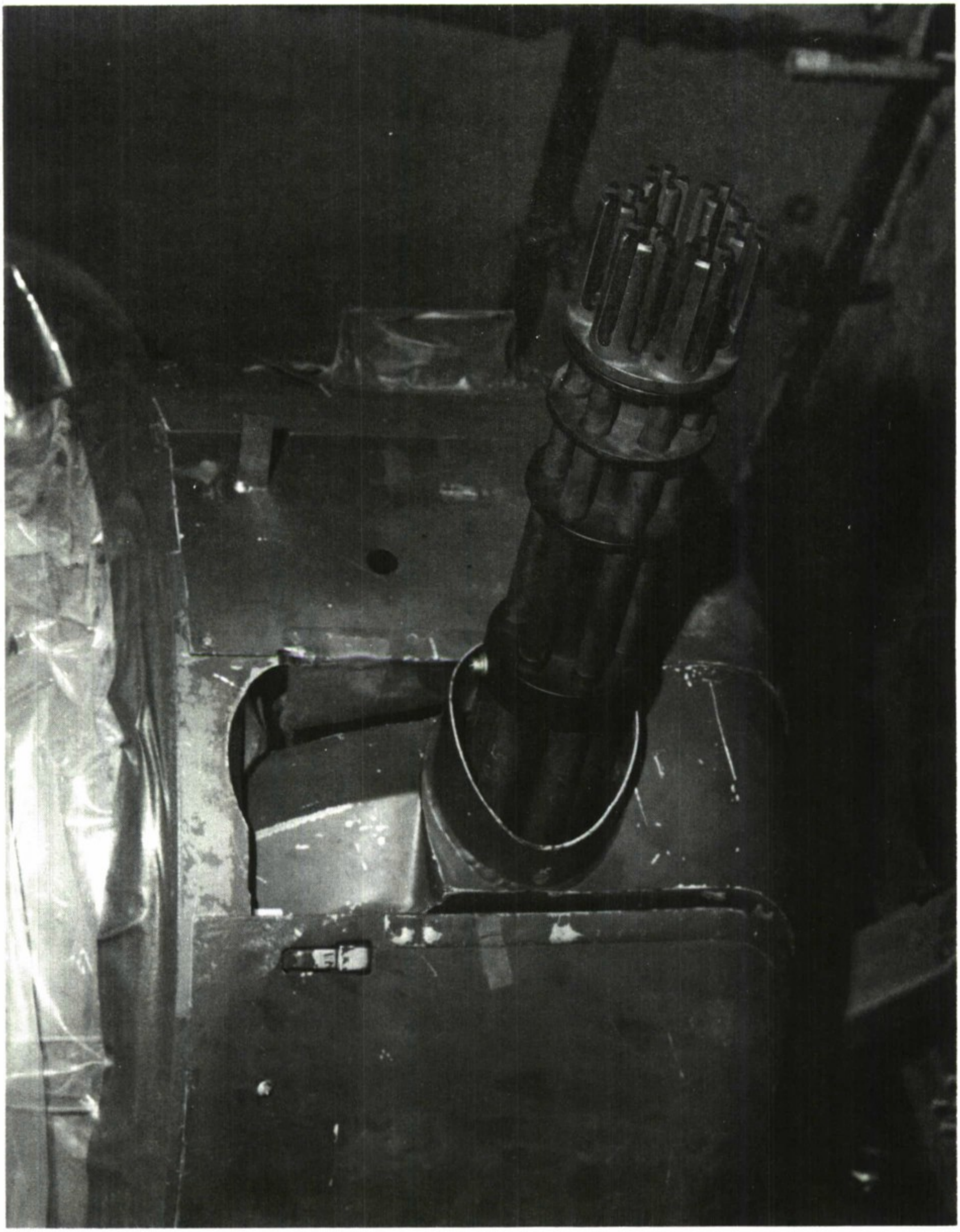

Fig. 4, TURRET WITH METAL SCALE ATTACHED

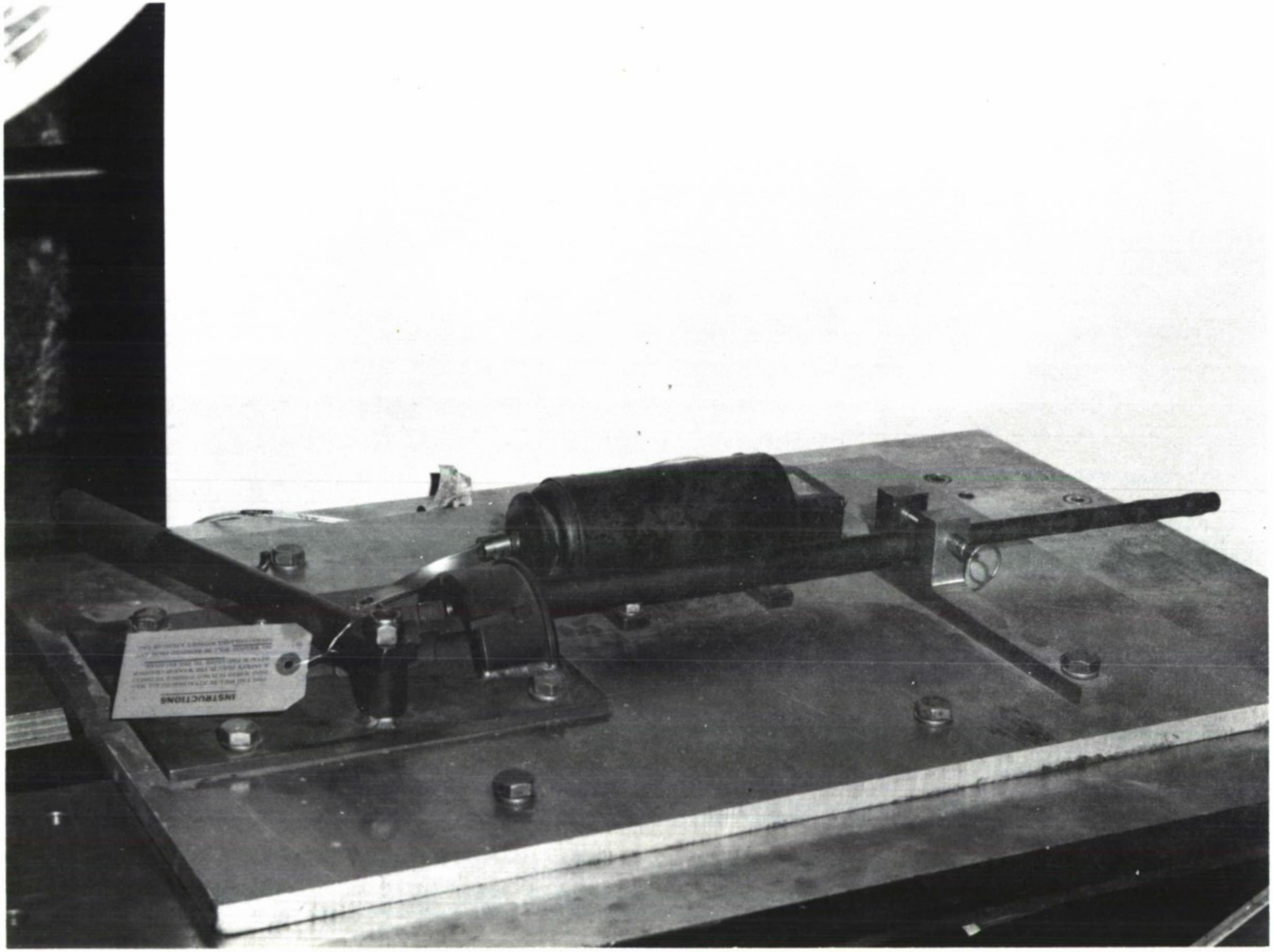

Fig. 5, TEST FIXTURE FOR SINGLE BARRELS

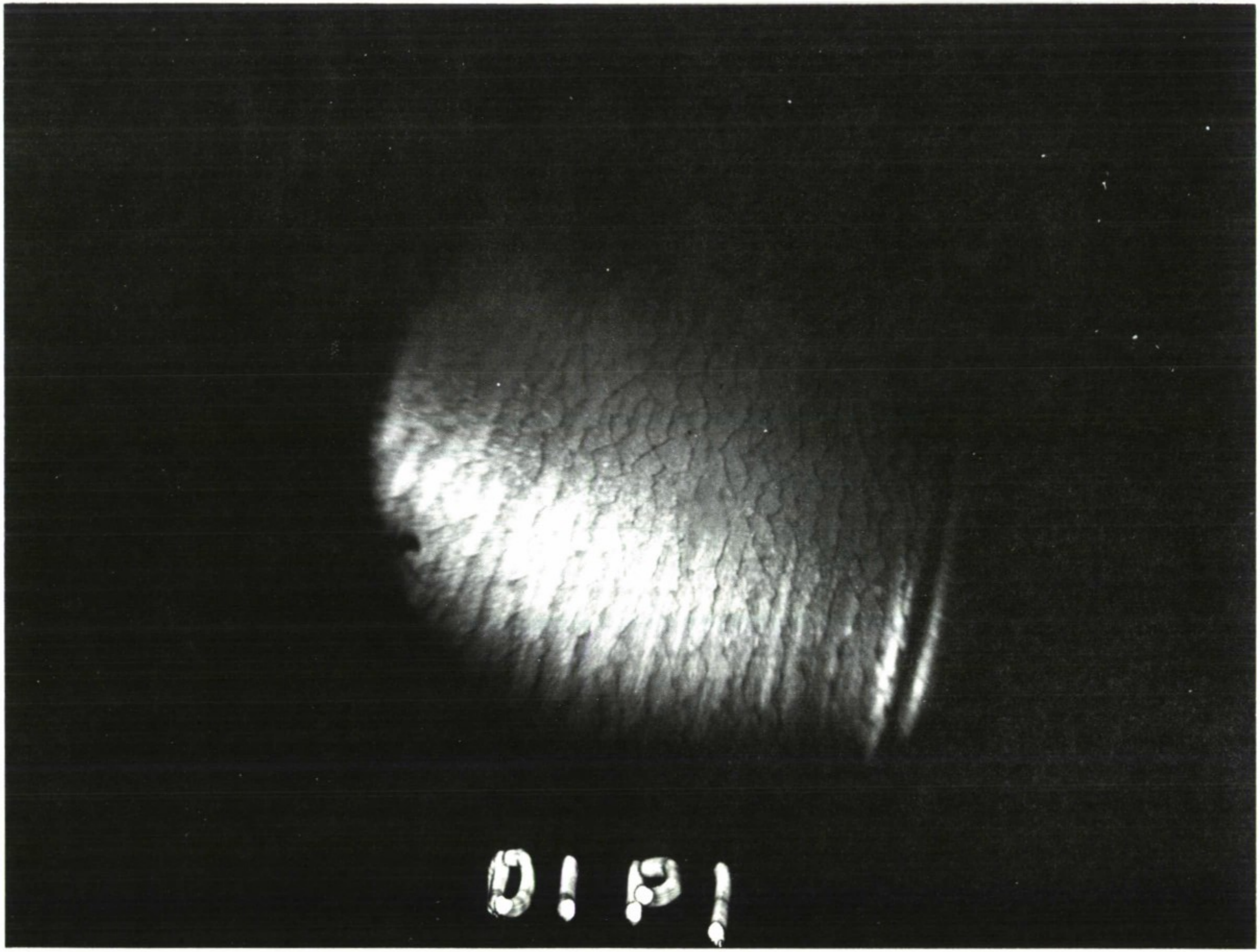

Fig. 6, BORE EROSION AREA

showed signs of erosion and heat checks (Figure 6). Bore measurements were also taken for some of the barrels (Tables A-3 and A-4). At the muzzle end of some of the barrels with the largest bulges, bore increase was noted to be .0160 inches. However, the maximum bore measurement at the muzzle was not obtained since the measuring device (air spindle) was limited to .0160 inch over bore tolerance limits. Bore measurements at the breech (for the breech ice plug) are inconsistent and therefore inconclusive. A small increase of approximately .001 inch was detected for .54 cc of ice, however, larger quantities of ice produced no increase in bore diameter.

The overall results indicate the following:

a. A small amount of ice in the muzzle (less than .54 cc) will not cause any barrel damage.

b. Cartridges frozen into the breech can be fired out without damage to the barrel.

c. Catastrophic failure (barrel blow-up) will not occur with ice plugs of up to 2.18 cc (1.84 inches) in the muzzle or breech.

2.3.2 Phase II, 7.62mm M134 Gun, Clear Mode, Without Flash Suppressor Test.

In this test, the M134, 7.62mm Automatic Gun was mounted in a M28A1 turret which was on a firing test stand (Figure 7). The complete system was placed in a cold room, coated with ice and test fired into the adjacent firing range. The turret had all fairings in place. All other openings which are normally inclosed by the aircraft or aircraft fairings were covered to prevent moisture from entering the turret in areas where it would not normally enter during actual flight conditions. The 40mm Grenade Launcher was not mounted in the turret; however, the opening in the fairing for this weapon was closed by tape. Four different ice thicknesses were used in this phase: 1/16 inch, 3/8 inch, 3/4 inch and 1 1/4 inch. See Figure 8 for gun with 1 1/4 inches of ice. After testing each ice thickness, the turret was thoroughly dried out. This was done to prevent the moisture of one test from causing any effect on succeeding tests. The M134 Gun has the capability of firing at 2,000 shots per minute (spm) or 4,000 spm when used in the M28A1 Turret. The lower rate of fire was used because it was thought to be a more severe test of the electric drive motor. The M134 Gun can also be used in the clear or unclear mode and can be used with or without a flash suppressor. In this particular phase, the clear mode of firing was used but the flash suppressor was not used. The clear mode was the only mode used in any phase for firing tests due to safety considerations. The single barrel tests of Phase I were used as an indication of the worst that could happen to the barrels during an unclear mode firing.

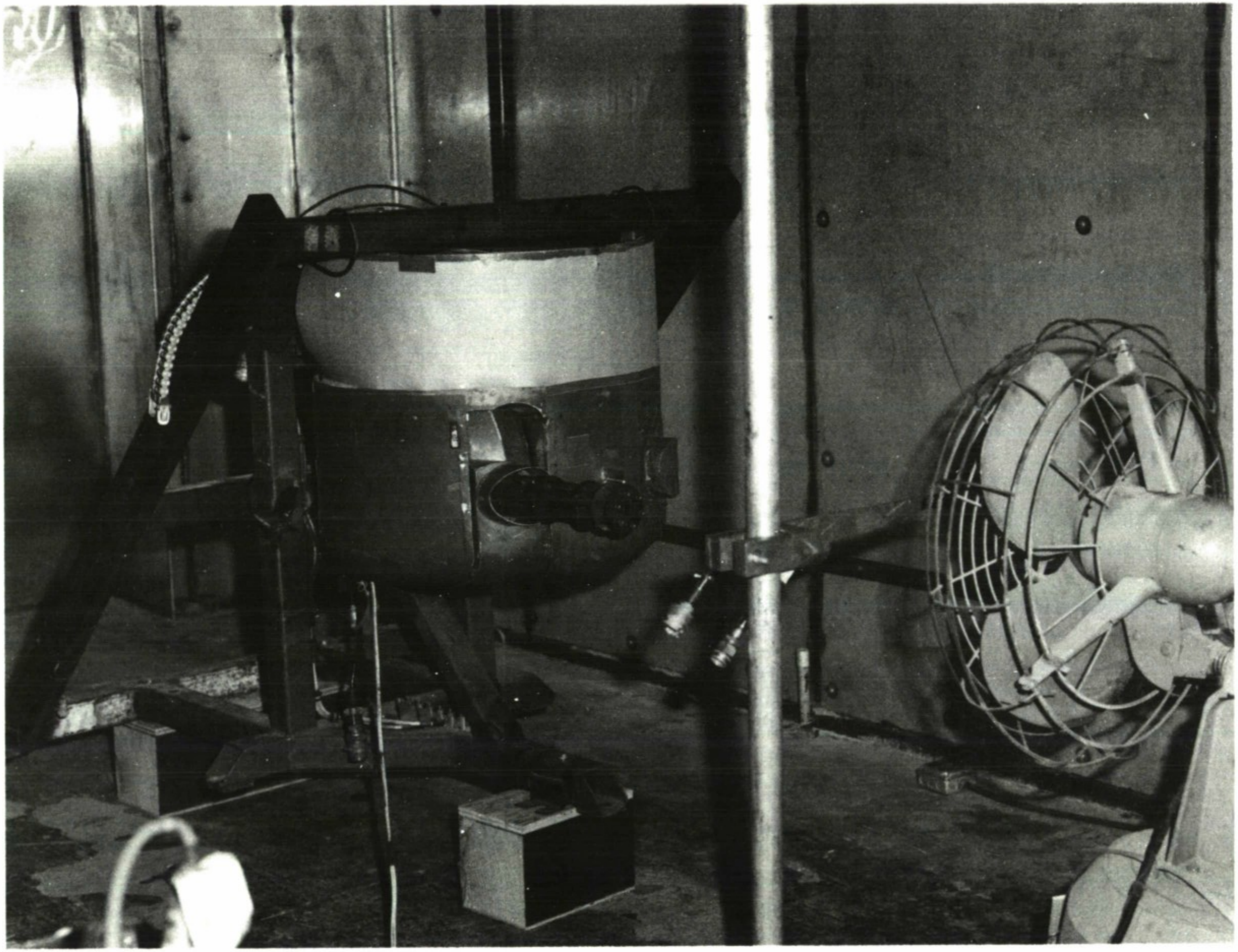

Fig. 7, M134 GUN WITHOUT FLASH SUPPRESSOR

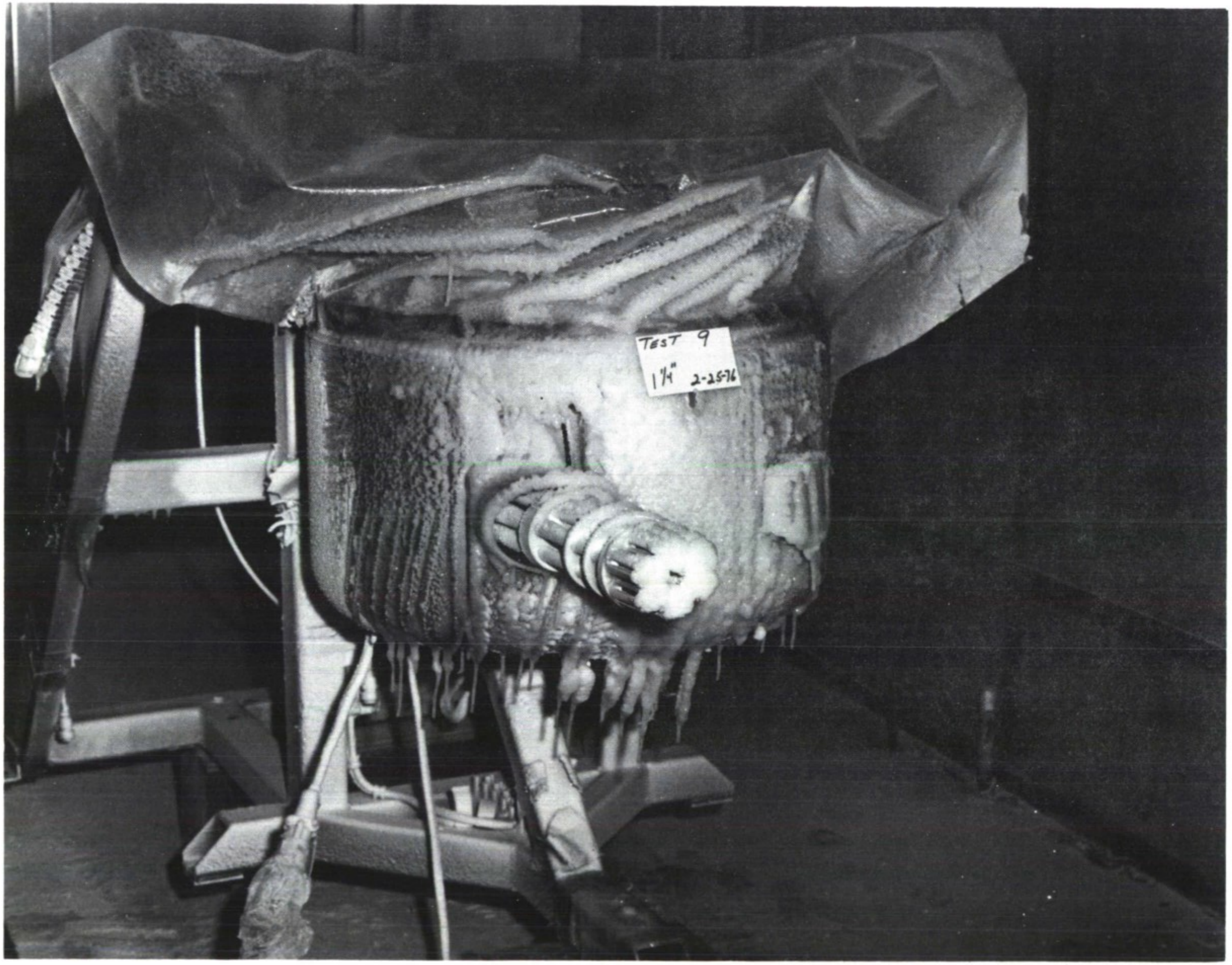

Fig. 8, M134 GUN WITHOUT FLASH SUPPRESSOR, COATED WITH 1 1/4 INCH ICE

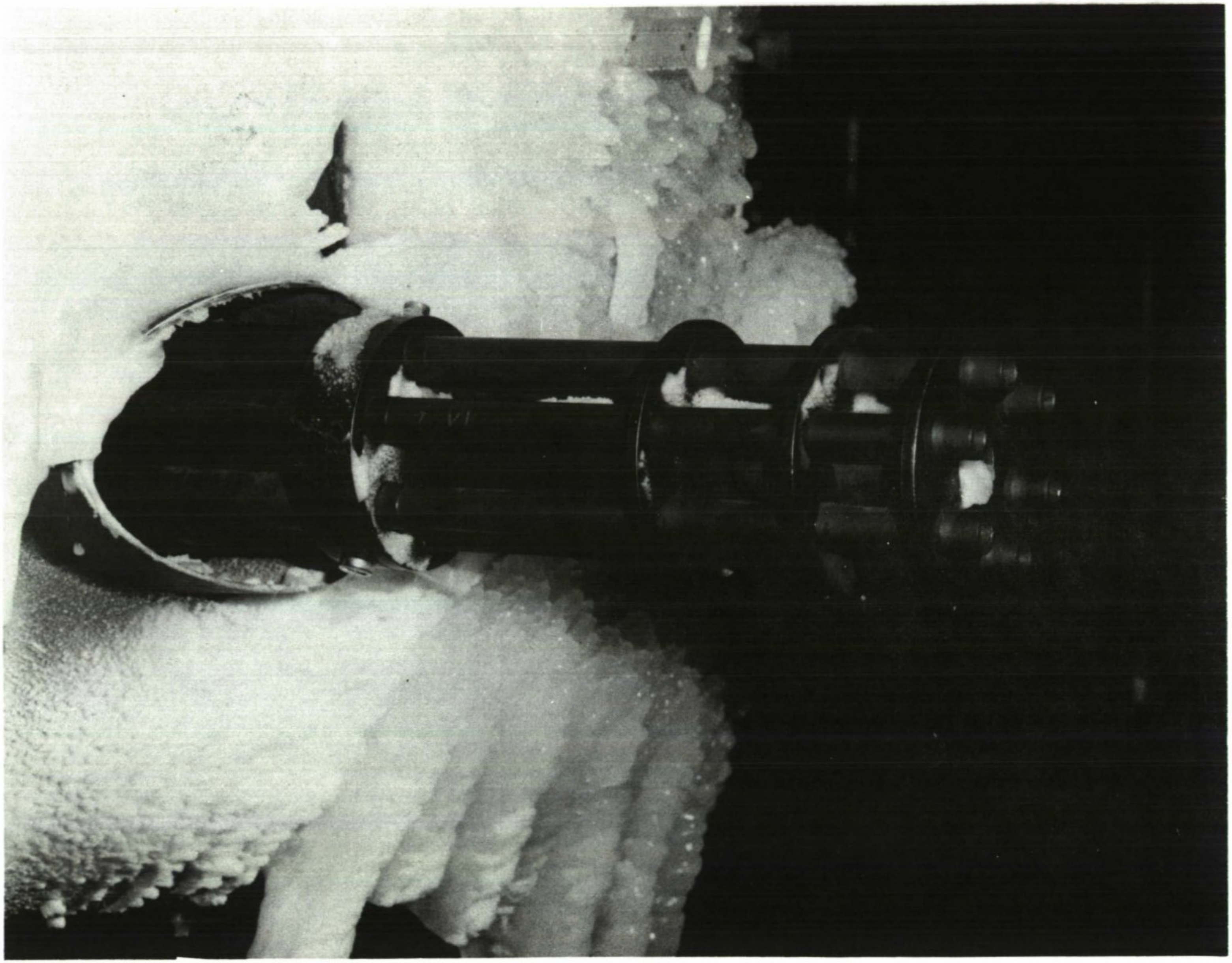

Fig. 9, M134 GUN, 1 1/4 INCH ICE AFTER FIRING

2.3.2.1 Phase II Test Results.

Bursts of 20 to 30 rounds were fired for each of the four ice thicknesses. The first few rounds in each firing broke all the ice loose from the muzzle (Figure 9) and the remaining rounds fired as they would under normal conditions. The gun did not start slowly or hesitate in any manner. During the period of ice build-up, ice started forming first around the rim of the muzzle. It kept building on the rim until the bore was completely closed. Ice did not appear to penetrate into the barrel to any great extent, however, the penetration was not actually measured. Table B-1 gives the basic parameters of this test. Bore measurements were taken before and after the firings (See Tables B-3 and B-2 respectively). Enlargements of the bore area were noted in 4 of the 6 barrels. Increases of .002 to .016 were measured at only one place which was one inch from the muzzle. Current (amperage), voltage and power curves were taken from the operation of the weapon's drive motor. These curves were obtained for ambient temperature, 1/16 inch, 3/8 inch, 3/4 inch and 1 1/4 inches of ice (See Figures B-1 through B-15). There does not appear to be significant differences between the ambient curves and those obtained from the iced conditions.

Overall results from this phase indicate that the M134 Gun can be fired with as much as 1 1/4 inches of ice on the muzzle without catastrophic failure. However, you will get some barrel damage. There may be some lesser amount of ice that the barrels could tolerate without damage, however, this amount was not determined by this test. The gun drive motor does not appear to be strained by a build-up of 1 1/4 inches of ice.

2.3.3 Phase III, 7.62mm, M134 Gun, Clear Mode, With Flash Suppressor.

This test was identical to Phase II in all ways except that a flash suppressor was mounted on the M134 Gun to determine the effect that this would have on the test weapon and barrels. (See Figure 10 for weapon coated with 1 1/4 inches of ice.)

2.3.3.1 Phase III, Test Results.

Bursts of 30 rounds each were fired for each of the four ice thicknesses. As in Phase II, the first few rounds broke all the ice loose from the nose end of the flash suppressor and all remaining rounds fired without any restrictions. Ice formed around and over the front of the nose of the flash suppressor but did not appear to penetrate inside of the barrel to any significant amount. The basic conditions of the test are shown in Table C-1. Bore measurements were made before and after the tests and are shown in Tables C-2 and

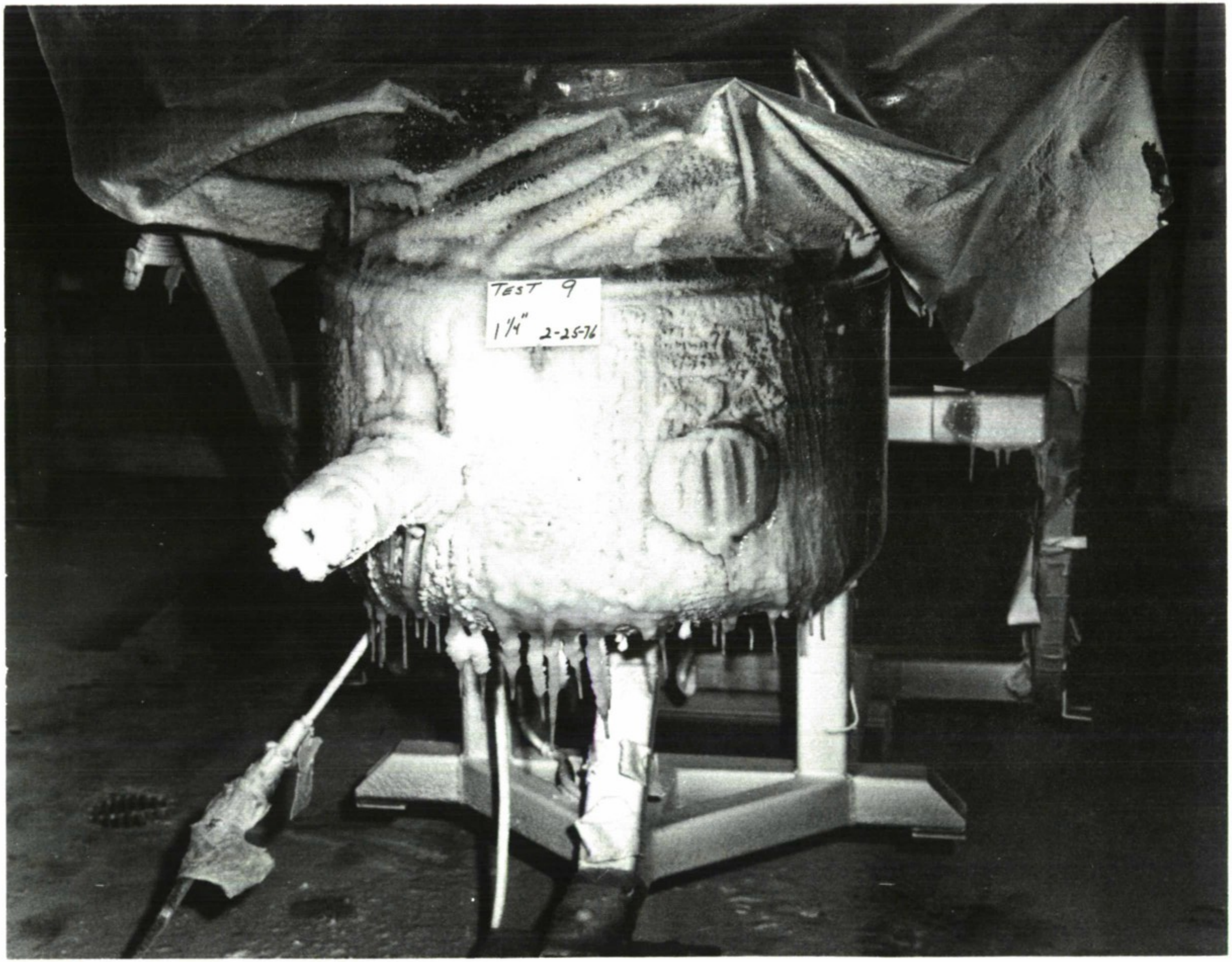

Fig. 10, M134 GUN WITH FLASH SUPPRESSOR, 1 1/r INCH ICE

C-3 respectively. Bore measurements taken after the test did not indicate any bulged bore areas. Curves were also made of the current, voltage and power requirements for the gun drive motor for ambient temperature, 1/16 inch, 3/8 inch, 3/4 inch and 1 1/4 inches of ice. These curves are shown in Figures C-1 through C-15. There did not appear to be any significant differences in the traces.

General results of this test are that the M134 Gun with flash suppressor can be fired with as much as 1 1/4 inches of ice on the muzzle without catastrophic failure and without any change to the barrel dimensions. The gun drive motor easily operates the gun under these conditions.

2.3.4 Phase IV, 40mm, M129 Grenade Launcher.

This phase was quite similar to Phases II and III, except that the M134 Gun was removed from the turret, the hole in the fairing for this gun was covered with tape, and the M129 was mounted in the turret on the opposite side from the M134. The Grenade Launcher (GL) has only one firing rate (425 spm) and it is automatically cleared at the end of each firing burst, so that there is no unclear firing mode with this weapon. The barrel for this launcher is not designed for a flash suppressor or muzzle brake.

2.3.4.1 Phase IV Test Results.

Bursts of three to five rounds were fired for each of the four ice thicknesses. Ice formed on the muzzle rim and gradually built up from this, however, the bore opening was never completely closed (Figure 11) even when the ice thickness reached 1 1/4 inches. The basic parameters for these tests are given in Table D-1. As shown in this table, the 1/16 inch test was rerun several times. On the first trial, the recorder did not operate. On the second and third trials the weapon jammed. Up to this point, inert HE rounds were being used. It was decided for safety reasons that the first round of the burst should be an inert practice round and the remaining ones would be inert HE. The fourth attempt to fire was successful. The 3/8 inch, 3/4 inch and 1 1/4 inch icing tests were conducted twice and on separate days to be sure that ice was not the main cause for the jam, which occurred during the 1/16 icing trial. A new barrel (No. 2) was put into the Grenade Launcher and the 1 1/4 inch ice test was conducted for the third time. This was done in the event that the barrels were found to be enlarged. This would determine if a one time firing at this thickness could cause barrel damage or if damage was being built up by successive tests. Bore measurements and O.D. measurements were taken prior to the tests as well as after. These results can be seen in Tables D-2 and D-3 respectively. There was no indication of

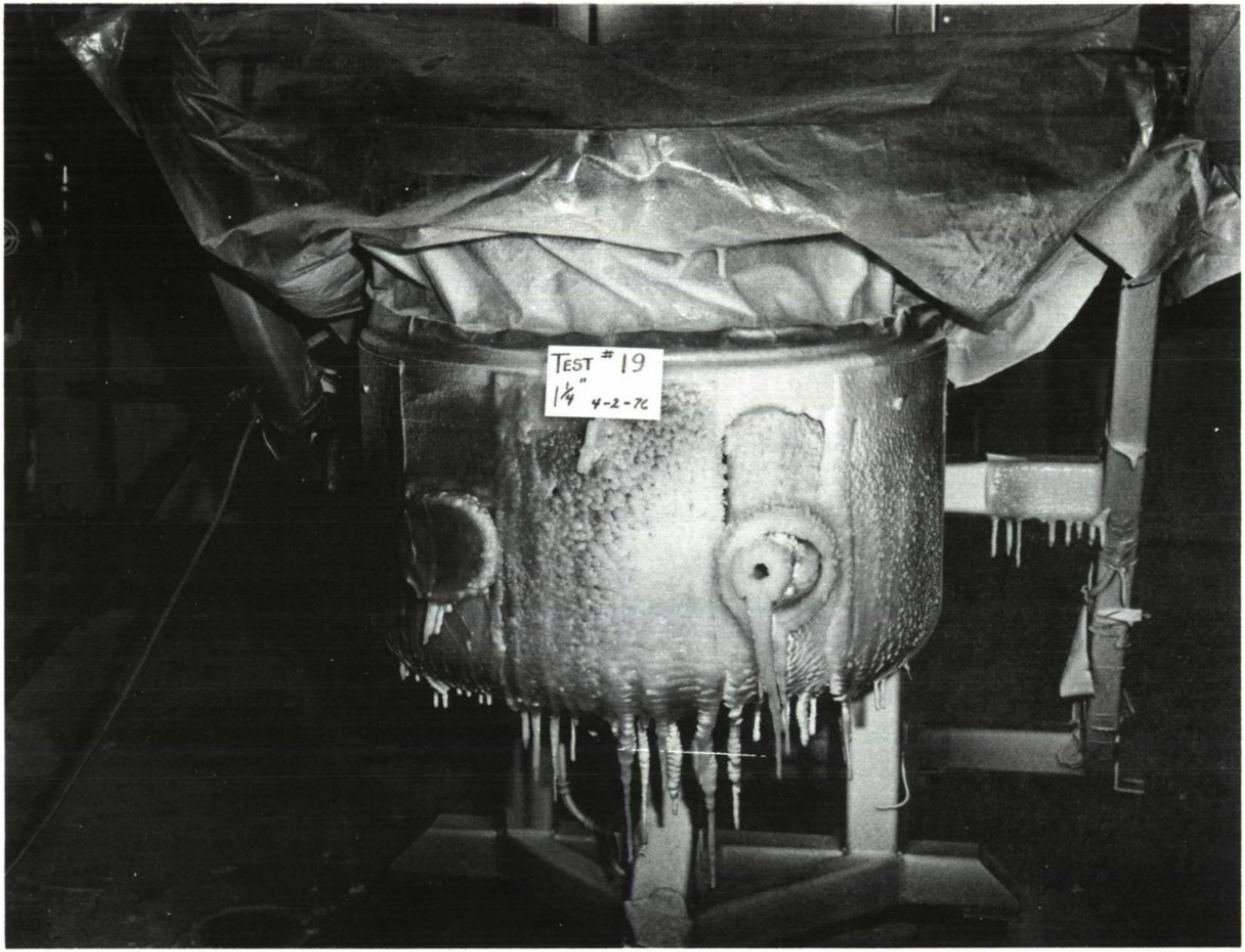

Fig. 11, M129 GRENADE LAUNCHER, 1 1/4 INCH ICE

any bore bulge or O.D. increase.

The first round in a burst was an inert practice cartridge, which was merely cycled through the launcher. The remaining rounds in all the bursts were inert HE rounds, which were fired through the barrel. They had a relatively soft nose or ogive surface. Pictures were taken of these rounds just after they left the muzzle and the rounds were also captured in a foam rubber mattress. There were no dents or any indication of damage to the ogive surface due to breaking through the ice barrier in the barrel muzzle.

Records were made of the current, voltage and power required to operate the grenade launcher drive motor. These are shown in Figures D-1 through D-15. Starting current, voltage and power remained about the same for all tests. The current normally drops off after the initial start-up, but then it increases a small amount as the gun starts to pull the ammunition into the breech. This second current surge gradually increased for each increase in ice thickness. At 1 1/4 inches of ice the current increased about 13%. The voltage curve did not change significantly for all trials. The power curve reflected the same increase as shown on the current curve. The drive motor had no problem in operating the iced grenade launcher.

General conclusions from this test are as follows:

a. The weapon can be operated without barrel damage with as much as 1 1/4 inches on the muzzle.

b. The soft nosed ogive of the projectiles are not damaged when fired through the muzzle ice.

c. Power requirements of the drive motor are more than adequate to overcome the ice.

2.3.5 Phase V, Turret Functioning Test.

This was purely a functional test; no weapons were fired. The turret was operated in azimuth to its extreme position in each direction. The weapons were also moved to their extreme positions in elevation and depression. Aircraft fairings, which mate with the turret, were attached to the test stand for this test. The purposes for this test were as follows:

a. Determine if the ice dam between turret and aircraft can be broken by available power.

b. Determine if guns can be elevated or depressed when coated with ice.

c. The clearance between the turret and aircraft fairing is rather close in one area. If a heavy layer of ice builds up on the turret, will the small clearance restrict the movement of the turret, or will damage result.

d. Will the motion of the turret and guns be slowed due to a coating of ice.

It should be noted that the turret is operated in azimuth by a hydraulic motor and the guns are elevated or depressed by a hydraulic cylinder. Hydraulic oil is provided at 5.5 gal. per minute at a pressure of 1500 psig.

2.3.5.1 Phase V Test Results.

The turret used for the first attempt at this test was old, much used and had been modified many times. The turret, under ambient temperature conditions, operated as desired in azimuth and elevation by means of a remote control box. However, when the turret was cold soaked and coated with ice, it became uncontrollable and would not respond to the remote control unit as desired. It did prove, however, that the ice bridges formed between the moveable and non-moveable components of the system did not stop or hinder the movement of the turret in azimuth or elevation.

A reconditioned M28A1 Turret was obtained which operated as required in the cold room, however, problems were encountered with the control unit. This phase was repeated with the reconditioned turret. The system was operated in azimuth and elevation at each of the four thicknesses of ice.

Data was obtained for turret velocities in azimuth and elevation and/or depression at ambient temperature and at 0°F (Table E-1). In elevation/depression the average velocity at ambient temperature was 103.5 degrees per second. At 0° the average velocity was 88.1°/sec, which is a decrease of 15.4°/sec. In azimuth the average velocity is 84.7°/sec at ambient temperature and 62.1°/sec at 0°F. This is a decrease of 22.6°/sec. No readings were obtained for the icing trials for the following reasons:

a. The instrumentation was set up so that the turret and weapons had to move from one extreme position to the other in both azimuth and elevation to obtain time of travel readings. This data could then be converted to velocity. The control box used for operating the turret was not designed for cold temperature operation. (The control unit was built to operate the turret from a test stand when the standard control panels, which are built into the Cobra Helicopter are not available). The control box at times was not capable of moving the

turret to its full extremes at the 0°F.

b. Ice got jammed into the stops and prevented the turret from covering its total excursion distance thereby not making contact with the instrumentation. It should be pointed out, however, that about 85% of the azimuth and elevation/depression distances were traversed by the turret and weapons.

c. Due to the quality of the control box, as soon as the power was turned on during the icing conditions, the turret made a quick initial movement before anyone touched the controls. This initial motion would make any timed readings inaccurate if they had been obtained.

General results of this test are as follows:

a. There was no problem in breaking the ice dam between moving and non-moving components in both azimuth and elevation.

b. The turret can be moved in azimuth and the guns can be moved in elevation/depression under heavy icing.

c. From a subjective standpoint, the motions in azimuth and elevation/depression appeared to be at about the same velocity, as they were during the 0°F readings.

d. Full excursion limits in azimuth and elevation/depression cannot be attained. However, approximately 85% of the excursion limits are possible.

e. In the test to determine if the turret with a build-up of ice on one surface can be turned past the narrow gap between aircraft fairing and turret, it was found that thicknesses of 1/16 and 3/8 inches of ice did not affect azimuth rotation. For ice thicknesses equal to or greater than 3/4 inches the turret stopped when the heavy iced section tried to go through the narrow gap.

2.3.6 Phase VI, 20mm, M195 Automatic Cannon.

This test was conducted with the 20mm, M195 Automatic Cannon mounted on a test stand (Figure 12). The M195 Gun is the weapon used with the M35 Armament Subsystem on the Cobra Helicopter. The M35 is a fixed weapon system in which the M195 Gun is mounted on the left hand wing of the Cobra. The gun has no fairing or other protection against atmospheric conditions. Therefore, no special protection was provided for this test. The spray nozzle was pointed directly at the gun muzzle. The M195 Gun fires at the rate of 750 spm, utilizes a muzzle gas deflector, and uses only a clear mode of fire. It is a six barrel, gatling type of weapon.

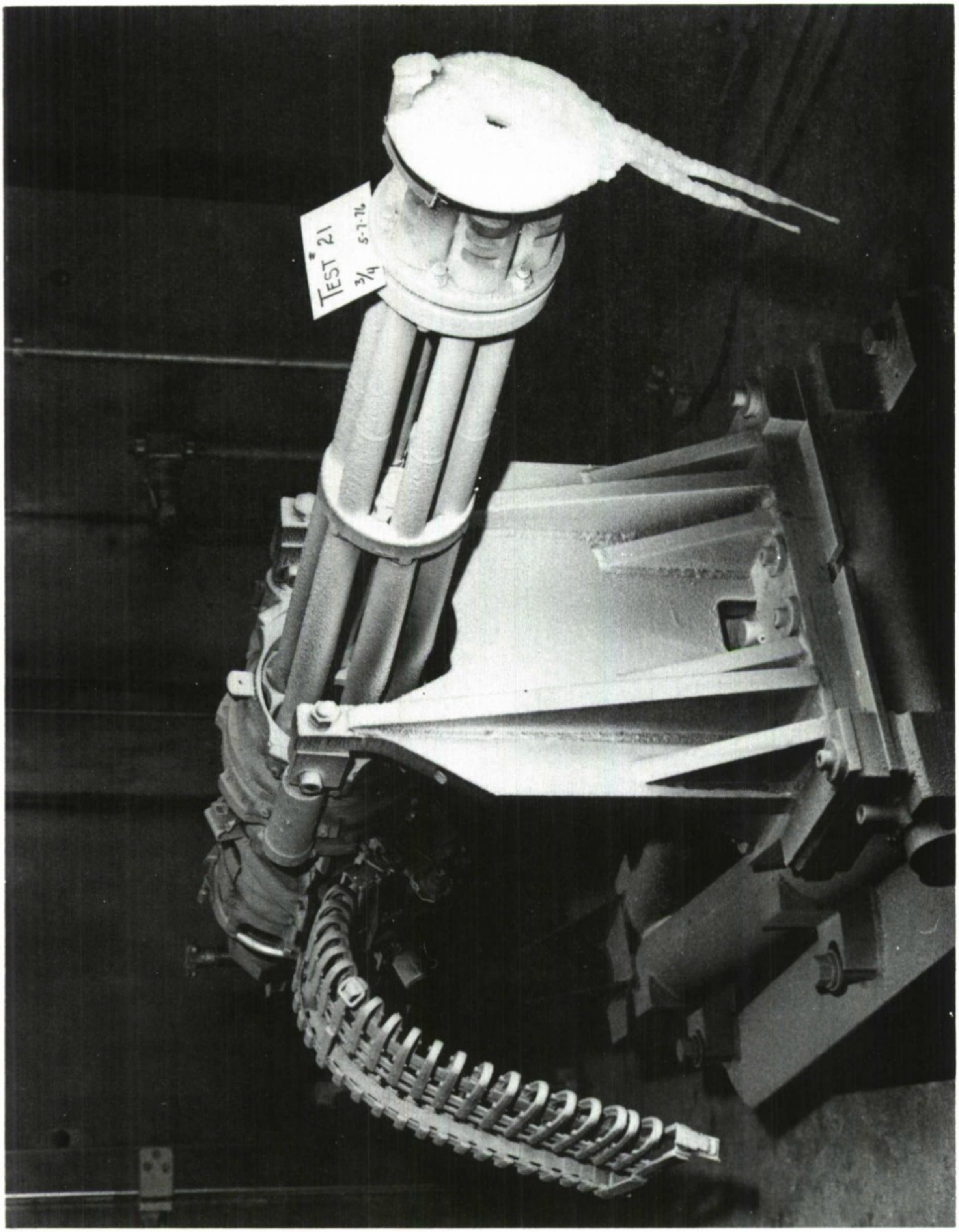

Fig. 12, M195 GUN, 3/4 INCH ICE

2.3.6.1 Phase VI, Test Results.

Bursts of 6 rounds each were fired for each of the four icing thicknesses. Ice collected mainly in the gas diffuser on the end of the barrels. The first round of each burst cleared out most of the ice in the diffuser without any difficulty. The remaining rounds fired under normal circumstances. There were no visual indications of barrel damage of any kind, although no actual bore or O.D. measurements were made. During the final burst at the 1 1/4 inch thickness of ice, the first five rounds fired but the sixth round jammed. It appeared that ice accumulation on the projectile prevented it from being chambered properly in the gun thereby causing it to jam the gun. This test was repeated using the 1 1/4 inch thickness of ice, however, no jam occurred during the second firing of 6 rounds. The rounds leading into the gun and feeder are in a flexible feed chute which is open to the atmosphere. Therefore, the possibility of ice forming on the cartridges in the chute is a very valid possibility. Due to the test apparatus, the water spray was concentrated towards the front of the weapon and did not coat the ammunition chute to the extent that might be encountered during an actual icing storm. It is, therefore, thought that heavy icing could cause problems for the 20mm, M35 Subsystem due to the open ammunition chute which allows ice to form on the cartridges. Current, voltage and power requirements for the gun drive motor are recorded in Figures F-1 through F-13. Only the current curve is available for ambient temperature. The voltage and current curves for ambient temperature were lost due to over-exposure to light. Current, voltage and power curves are available for -4°F. Starting current was approximately 11% higher for -4°F than for ambient. There was no significant difference between the current, voltage and power curves for -4°F with those for the iced tests.

General results from this test are as follows:

a. The weapon can be fired without catastrophic failure or any other serious problems after having been heavily iced. However, it may be necessary to provide some protection for the ammunition in the flexible chute which leads from the ammunition box to the gun feeder.

b. Ice on the gun does not put any noticeable strain on the gun drive motor.

2.3.7 Phase VII, Evaluate Ice Prevention Methods.

Provisions were made in the evaluation program to test any commercial products, devices or techniques which will prevent the formation of ice or eliminate any undesirable effects caused by icing.

2.3.7.1 Phase VII, Test Results.

Two approaches to ice prevention were conceived for the M28A1 Armament Subsystem prior to this program and a third approach was found during the tests. However, the results of the icing evaluation tests indicate that light and moderate icing will not really cause any problems for the M28A1 Armament Subsystem. It is assumed that if heavy icing is encountered, the aircraft would either land or fly out of the atmospheric condition as soon as possible. Therefore, it does not appear necessary to provide any ice prevention devices. However, it was felt necessary to investigate this phase in the event that it is desired to prevent heavy icing or to have the capability of operating during heavy icing conditions.

The two original approaches examined were as follows:

a. Move the turret 110° to the side away from wind, move the weapons to minus 50° depression and leave the turret in this position during the flight through icing conditions. The reasoning for this being that water would not enter the barrels in this position and would only form ice on the sides of the barrels and turret. Test results showed that ice did not build up inside the barrels to any large degree even when they were pointed directly at the wind and rain source. The build-up of ice between movable and non-movable parts was easily overcome by elevation drive cylinder and the hydraulic azimuth drive. However, when the build-up of ice on the side of the turret became greater than 3/8 inch thick, the turret could not turn when the area of built up ice came to the narrow gap between turret and aircraft fairing. Therefore, this approach is not recommended.

b. Apply a substance to the surface of the turret which will inhibit the accumulation of ice. A commercial product was found which seemed to have promising ice inhibiting characteristics. It is called Aero Cream Surface Protector, Wag-Aero Company, Box 181, Lyone, Wisconsin, Zip Code 53148. This is a liquid cream substance that acts like a liquid wax. It is poured onto a cloth, rubbed onto the desired surface and when dry, forms a white powdery surface which should be wiped off.

This cream was tried under several different circumstances as follows:

1. The cream was applied to an auto window which was normally parked outside overnight during cold weather and normally became completely frost covered. The first morning after the application, the test window was frost free whereas all the other windows were completely frost covered. The second morning, the test window was about 40% frost covered and the third morning, there was very little difference between the test window and the uncoated ones.

2. The cream was applied to the plexiglass windshield of a light airplane. This was not tested in icing conditions, but was tested in rain. It was found that rain water formed large droplets and ran off the windshield keeping it fairly clear. It was also noted that bugs did not cling to the treated windshield nearly as much as untreated surfaces. Also, those bugs that did stick to the windshield were easily wiped off. This capability has lasted for several months.

3. The third test of this cream was on the turret in the cold room. Water was sprayed on the turret as usual but instead of freezing to the surface, it formed large globules and rolled off. Later, the water turned to slush which slid off and finally it froze to the surface. The turret was then maneuvered and it appeared that the ice broke loose more easily than it did prior to treatment. The overall result appeared to be that it took a much longer time for ice to start forming and that it was more easily broken loose once it had formed. It should be noted here, as stated earlier, that the temperature was held at 0°F during the application of ice to the turret and guns. It is thought that this temperature is more extreme than would normally be encountered during a natural ice storm. The possibility exists, therefore, that ice would never form on the turret treated with Aero Cream under natural icing conditions. However, this is only speculation and should be tested.

4. A small piece of aircraft fairing was cut from a larger section and treated with the cream which resulted in an undesirable side effect. The fairing was aluminum honeycomb with a fiberglass skin bonded to it. A few days after the cream was applied, the skin material came loose from the honeycomb core. During the test described in paragraph 3., above, the cream was applied to similiar aircraft fairing (honeycomb), as well as, the turret fairing (woven glass cloth covering a cellular cellulose acetate core). These surfaces were checked about three months after the conclusion of the test with the Aero Cream and there was no evidence of any separation between core material and skin for either the aircraft fairing or the turret fairing.

The third approach for using a weapon system in icing conditions is to use a gas deflector or flash suppressor on the barrel muzzles. The deflector or suppressor collects the ice leaving the barrel muzzle relatively free of ice. The projectile and gun gas leaves the barrel without any sudden pressure build-up. The projectile can penetrate the ice in the deflector/suppressor without any problem. For barrels 40mm and larger, no protection is required for ice thicknesses up to 1 1/4 inches, because the muzzle does not become completely plugged.

The general results of this test show that a gas deflector or flash suppressor should be used for weapons under 40mm to operate safely in icing conditions up to 1 1/4 inches. The 40mm and larger

weapons do not require any protection. The turret should be faced into the wind. A protective cream can be used but it is not really necessary.

2.3.8 Phase VIII, 40mm Barrel Test.

In this test an ice plug was frozen into the muzzle end of the 40mm barrel and one round was fired to determine the damage that might be caused by this situation. The test was repeated four times with a progressively thicker plug of ice being used. The ice plugs progressed as follows: 0.5 inch, 1.0 inch, 1.5 inch and 2.0 inch.

2.3.8.1 Phase VIII, Test Results.

The results from this test, shown in Tables G-1 and G-2, indicate that the 40mm barrel can be fired with a 2 inch plug of ice in the muzzle without catastrophic failure, however, the barrel did become enlarged by .0145 inches at the plug end, which faces the breech. Two barrels were used in this test. The first barrel (called barrel #2, in Table G-1) was run through the full gamut of tests using 0.5, 1.0, 1.5 and 2.0 inch ice plugs in the muzzle. Outside diameter (O.D.) measurements were made at points 1.0, 2.0, 3.0, and 4.0 inches from the muzzle. No appreciable difference was noted for the outside measurements when firing the barrel with the 0.5 inch ice plug in it. The 1.0 inch ice plug caused a slight increase of O.D. measurements from .001 to .002 inches. The 1.5 inch ice plug caused the O.D. of the barrel to increase in size by .007 over the original barrel size at the 1.0 inch location. However all other locations did not show any basic change in size from the 1.0 inch plug firing. Results from use of the 2.0 inch ice plug showed no change in O.D. at the 1.0 inch location, an increase of .0145 (from original O.D.) at the 2.0 inch location and an increase of .0025 at both the 3 inch and 4 inch locations (as compared to original O.D.). The second barrel (called barrel #1, in Table G-2) was fired only once. On this test an ice plug of 1.5 inch in the muzzle was used. There was no difference in I.D. measurements at any of the 4 measurement locations after firing.

General results indicate the following:

a. Catastrophic failure will not occur when firing a launcher with as much as 2 inches of ice in the muzzle of the 40mm barrel.

b. A single firing with ice in the muzzle will not necessarily cause barrel damage, however, a series of plugged bore firings will cause barrel bulge and it will gradually get worse.

c. The relatively soft ogive of the inerted M384 cartridges used in this test were flattened a small amount when fired in these plugged barrels. It was most noticeable with the 1 1/2 and 2 inch ice plugs.

3. <u>Conclusions</u>:

As stated earlier, TRADOC desires that the helicopter fleet have the capability of operating in light to moderate icing conditions. The conditions used in this test are considered to be more severe than would be encountered under actual operating conditions in regards to ice thickness. Keeping in mind the test limitation of attaining a simulated forward speed of 13 knots, the results indicate that heavy icing (up to 1 1/4 inches) does not present any severe problems for the M28A1 Turret, the M134 Gun in the turret, the M129 Grenade Launcher in the turret and the M195 Gun. There are some limitations, however. The M134 Gun requires the use of a gas deflector or flash suppressor to prevent the barrels from becoming slightly bulged. The turret power units had no problem in breaking the ice dam between the moving and non-moving parts and the drive motor for each weapon had no problem in operating as required. Ice jammed into the stops caused some limitations in azimuth and elevation movement. Approximately 85 percent of the excursion limits in each direction were still possible. The weapons were able to operate at full speed. Elevation and azimuth velocities were slower than for ambient temperatures but did not appear to vary much from the cold temperature (-4°F) velocities without ice.

Ammunition in the flexible chuting to the M195 Gun is open to icing conditions and can result in feed jams because ice forms on the cartridges and jams as the rounds are being fed into the gun. This probably would occur only at conditions of very heavy icing.

It was noted during the testing that ice first started forming on the end rim surface of the barrel muzzle. Ice formed faster on the front surface of the rim but it also formed around the outside and inside surfaces of the rim. For the smaller caliber weapons, the barrel muzzle became completely covered with ice quite rapidly. The 40mm barrel never did become completely closed with ice even when as much as 1 1/4 inches of ice was deposited on the turret. Water and, therefore, ice did not appear to penetrate very far into the barrel even though the water spray and fan were aimed horizontally and at the front of the turret, just slightly offset from the gun muzzle. It is assumed that the air already in the gun barrel could not escape fast enough to allow the high speed air to enter. This conclusion was drawn from the fact that ice appeared to penetrate only slightly into the barrel and did not cause any problems in the breech area.

Ice 1 3/4 inches thick was frozen into the muzzle of a 7.62mm barrel and two inches of ice was frozen into muzzle of the 40mm barrel. Both barrels were fired without catastrophic failure. It

is the opinion of the testing personnel that any amount of ice that might accumulate on the weapons naturally during flight would not cause a catastrophic failure in the weapon when fired.

De-icing methods were not tested thoroughly, however, it does appear that Aero Cream does delay the formation of ice and might be much more effective at a temperature which is closer to actual atmospheric icing conditions (a few degrees below 32°F). Acutal test temperature which was approximately 0°F is considerably more severe than natural icing conditions and was used to expedite the test. Positioning the turret with the guns pointing down and away from the wind direction did not prove to be a proper method of operation during icing conditions since a build-up of ice occured on the windward side of the turret which could not be forced by turret power past the narrow gap between turret and aircraft fairing. Thus the maneuverability of the turret was limited in one direction. A better approach it appears would be to face both the turret and weapons into the wind. The turret has the capability of breaking the ice dam between moveable and non-moveable parts in both elevation and azimuth.

The relatively soft ogive of the inert 40mm M384 cartridge was not dented or damaged in any way when fired through barrels that were coated with 1 1/4 inches of ice. These cartridges were flattened somewhat on the nose when fired through the 1 1/2 inch and 2 inch ice plugs.

4. Recommendations:

The findings of this test should be confirmed by conducting aerial firing tests during icing conditions in which the turret and weapons are faced into the wind.

A gas deflector or flash suppressor should be used on all weapons smaller than 40mm during icing conditions when the total accumulation can get to be as much as 1 1/4 inches.

The use of a cream or de-icing surface is not required for use on the turret or guns, however, it may be of use on the rotor blades or other aircraft surfaces. It is, therefore, recommended that Aero Cream be studied for use on other aircraft surfaces.

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APPENDIX A

PHASE I DATA

7.62mm Single Barrel Tests

TABLE A-1

7.62mm Barrel O.D. Measurements

Barrel No.	Type of[b] Ice Plug	Rds Fired	Amt. of[c] Water Cu. Cms.	11/16 in.[d]	1 1/4 in.[e]	2 in.[f]
4[a]	0	0	N/A	.6175	.538	.876
5[a]	0	1	N/A	.6175	.541	.883
1	A-1	1	.27	.6175	.540	N/A
2	A-2	1	.27	.618	.538	N/A
3	A-3	1	.27	N/A	N/A	.887
4	B-1	1	.54	.620	.542	N/A
5	B-2	1	.54	.630	.540	N/A
6	B-3	1	.54	N/A	N/A	.878
7	C-1	1	.82	.631	.541	N/A
8	C-2	0	.82	Water Did Not Freeze		
9	C-3	0	.82	Water Did Not Freeze		
10	D-1	1	1.09	.630	.573	N/A

TABLE A-1 (Cont.)

7.62mm Barrel O.D. Measurements

Barrel No.	Type of Ice Plug[b]	Rds Fired	Amt. of Water Cu. Cms.[c]	11/16 in.[d]	1 1/4 in.[e]	2 in.[f]
11	D-2	1	1.09	.631	.538	N/A
12	D-3	1	1.09	N/A	N/A	.877
13	E-1	1	1.64	.629	.566	N/A
14	E-2	0	1.64	Water Did Not Freeze		
15	E-3	1	1.64	N/A	N/A	.880
16	F-1	1	2.18	.619	.569	N/A
17	F-2	1	2.18	.631	.558	N/A
18	F-3	1	2.18	N/A	N/A	.879

Notes:
a. These were control barrels which were measured prior to their use in the icing tests. Barrel no. 4 was not fired prior to taking bore measurements. Barrel no. 5 was fired once prior to taking bore measurements.

b. Each barrel was assigned a letter plus a numeral. The letter represents the amount of water poured into the barrel and the numeral indicates the position in which the barrel was held during the freezing process. See below for identification of barrel positions:

Position #1 Muzzle pointing straight down

TABLE A-1 (Cont.)

7.62mm Barrel O.D. Measurements

Position #2 Muzzle down at 45° to vertical

Position #3 Cartridge in chamber with muzzle pointing up at 45° to vertical

c. Conversion from cu. cms. of water to vertical depth in inches (does not include bbls tilted at 45°) is as follows:

.27 cu. cms. = .228 in depth in bore

.54 cu. cms. = .456 in depth in bore

.82 cu. cms. = .692 in depth in bore

1.09 cu. cms. = .920 in depth in bore

1.64 cu. cms. = 1.385 in depth in bore

2.18 cu. cms. = 1.840 in depth in bore

d. Measurement was made on the Outside Diameter (O.D.) of the barrel at a distance of 11/16 inches from the muzzle. Barrel drawing (F 1170120 4) dimension at this point is .619 dia -.002.

e. Measurement was made on the O.D. of the barrel at a distance of 1 1/4 inches from the muzzle. Drawing dimension at his point is .543 dia -.010.

f. Measurement was made on the O.D. of the barrel at a distance of 2 inches from the breech. Drawing dimension at this point is .890 dia -.015.

TABLE A-2

Over-Tolerances on 7.62mm Barrels

O.D. Measurements

Barrel No.	Type of[b] Ice Plug	Amt. of[c] Water Cu. Cms.	11/16 in.[d]	1 1/4 in.[e]	2.0 in.[f]
4[a]	0	N/A	0	0	0
5[a]	0	N/A	0	0	0
1	A-1	.27	0	0	N/A
2	A-2	.27	0	0	N/A
3	A-3	.27	N/A	N/A	0
4	B-1	.54	+.001	0	N/A
5	B-2	.54	+.011	0	N/A
6	B-3	.54	N/A	N/A	0
7	C-1	.82	+.012	0	N/A
8	C-2	.82	Water Did Not Freeze		
9	C-3	.82	Water Did Not Freeze		
10	D-1	1.09	+.011	+.030	N/A

TABLE A-2 (Cont.)

Over-Tolerances on 7.62mm Barrels

O.D. Measurements

Barrel No.	Type of[b] Ice Plug	Amt. of[c] Water Cu. Cms.	11/16 in.[d]	1 1/4 in.[e]	2.0 in.[f]
11	D-2	1.09	+.012	0	N/A
12	D-3	1.09	N/A	N/A	0
13	E-1	1.64	.010	+.023	N/A
14	E-2	1.64	Water Did Not Freeze		
15	E-3	1.64	N/A	N/A	0
16	F-1	2.18	0	+.026	N/A
17	F-2	2.18	+.012	+.015	N/A
18	F-3	2.18	N/A	N/A	0

Notes: See notes for Table A-1.

TABLE A-3

7.62mm Barrel Bore Measurements

Single Barrel Firings

Distance from Breech	Control BBL No. 4	Control BBL No. 5	BBL No. 3 (A-3)	BBL No. 10 (D-1)	BBL No. 11 (D-2)	BBL No. 13 (E-1)	BBL No. 16 (F-1)	BBL No. 17 (F-2)
3"	.3000	.3000	.3010	.3002	.2999	.3005	.3008	.3002
6"	.2998	.3000	.3002	.3002	.3000	.2995	.3008	.2998
9"	.2998	.3000	.3000	.3000	.2998	.2995	.3005	.2990
12"	.2990	.3000	.3000	.2999	.2998	.2998	.3000	.2989
15"	.2990	.3000	.3005	.2999	.3000	.2990	.2999	.2988
18"	.2990	.2998	.3000	.2995	.2989	.2989	.2999	.2985
20"	.2988	.2995	.3000	.3100	.2995	.3170	.3170	.2985
21"	.2993	.3000	.3005	.3170+	.3170+	.3170+	.3170+	.3170+

Notes: a. Measurements under the line are over tolerance. Drawing dimension for bore is .2995 dia +.0015. Maximum amount of barrel enlargement is .0160 inch.

TABLE A-4

7.62mm Barrel Bore Measurements

Single Barrel Firings With Cartridge Frozen Into Breech

Distance from Breech	BBL No. B-3	BBL No. D-3	BBL No. E-3	BBL No. F-3
2"	.3000	.2990	.2995	.3000
4"	.3000	.2993	.2995	.3005
7"	.3000	.3000	.3000	.3005
10"	.3008	.3000	.3000	.3008
13"	.3018	.3001	.3000	.3010
16"	.3000	.3002	.3002	.3010
18"	.3020	.3005	.3005	.3010
19"	.3025	.3005	.3010	.3015
20"	.3010	.3005	.3005	.3010

Note: Drawing dimension for bore is .2995 dia +.0015. Total barrel length is 22 inches.

APPENDIX B

PHASE II DATA

7.62mm, M134 Gun, Clear Mode,

Without Flash Suppressor

TABLE B-1

M134 Gun Without Flash Suppressor

Fired	Type of Fire	Rate of Fire	Airflow, ft./min.	Ice[b] Accum.	Temp. of Room	Operating Voltage
20	Auto	2379 spm	N/A	N/A	Ambient	28V
25	Auto	1783 spm	1200 fpm	1/16"	0°F	25V
30	Auto	1855 spm	1200 fpm	3/8"	0°F	25V
30	Auto	1886 spm	1200 fpm	3/4"	0°F	25V
30	Auto	2906 spm[a]	1200 fpm	1 1/4"	0°F	25V

Notes: a. The 2906 spm rate of fire appears to be exceptionally high. An electronic screen was used to measure rate of fire. It is believed that ice from the muzzle of the gun also went through the screen and the screen could not differentiate between ice particles and projectiles. This could account for this high rate.

b. It took approximately 20 minutes to accumulate 1/16 inch of ice on the turret and 40 minutes to accumulate 1 1/4 inches of ice.

TABLE B-2

M134 Gun Without Flash Suppressor

Bore Measurements After Icing Test

Distance From Breech	Barrels[a]					
	#1	#2	#3	#4	#5	#6
3"	.3010	.3010	.3018	.3005	.3010	.3005
6"	.3000	.3010	.3005	.3005	.3005	.3005
9"	.3000	.3010	.3010	.3005	.3010	.3000
12"	.2998	.3015	.3008	.3005	.3010	.2998
15"	.2998	.3010	.3008	.2995	.3008	.2998
18"	.2998	.3008	.3005	.2990	.3005	.2998
21"	.3170	.3030	.3000	.2990	.3005	.3050

Note: a. Drawing dimension for the bore is .2995 dia +.0015.

TABLE B-3

M134 Gun Without Flash Suppressor

Bore Measurements Before Icing Test

Distance From Breech	Barrels[a] #1	#2	#3	#4	#5	#6
3"	.3010	.3000	.3000	.3005	.3005	.3002
6"	.2998	.3005	.3005	.3005	.3002	.3000
9"	.2995	.3008	.3000	.3002	.3000	.2998
12"	.2995	.3000	.3000	.2998	.3005	.2995
15"	.2995	.3008	.3008	.2995	.3000	.2995
18"	.2988	.3005	.3005	.2990	.3000	.2993
21"	.2988	.3000	.3000	.2985	.2998	.2990

Note: a. Drawing dimension for the bore is .2995 dia +.0015.

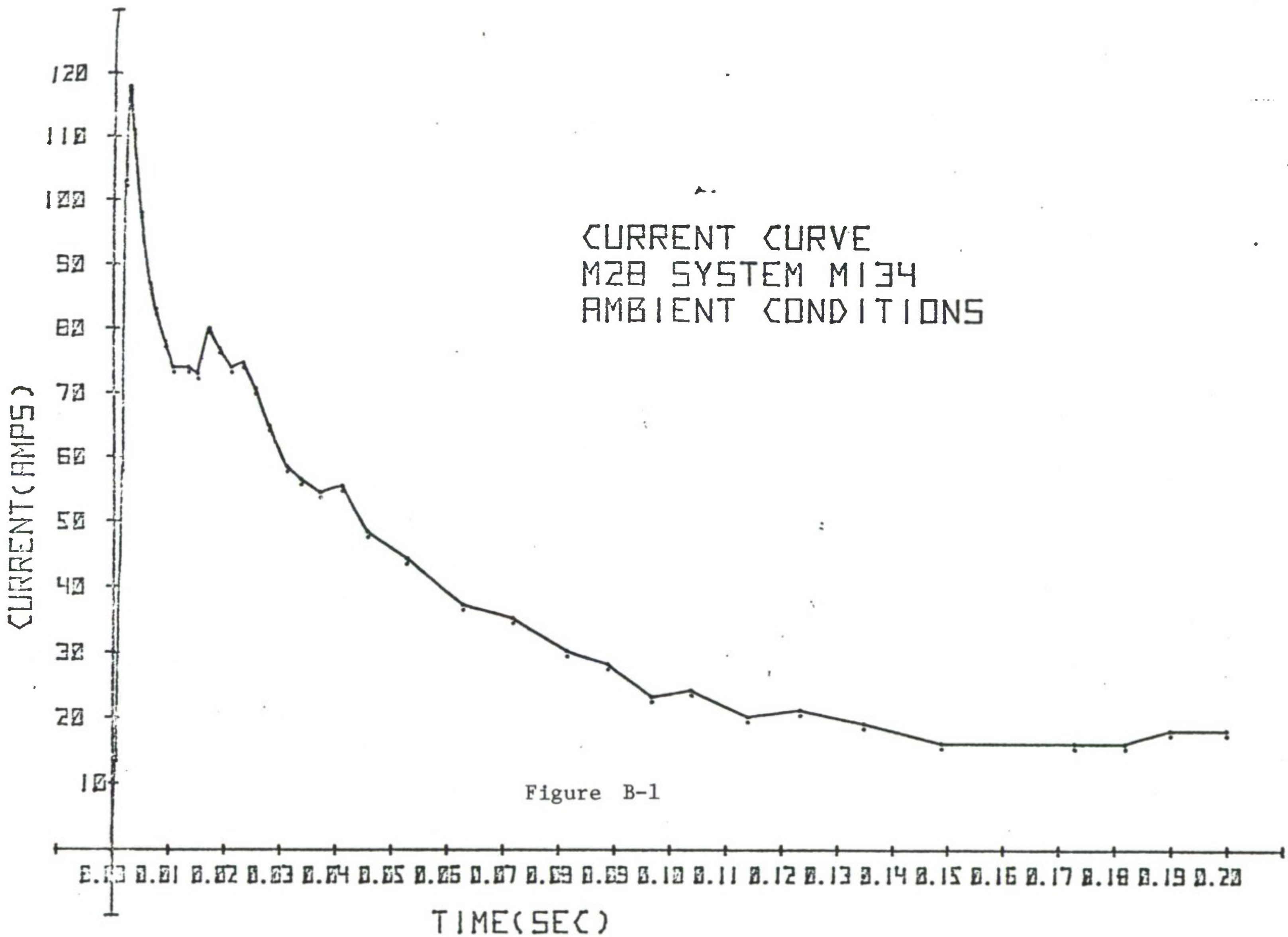
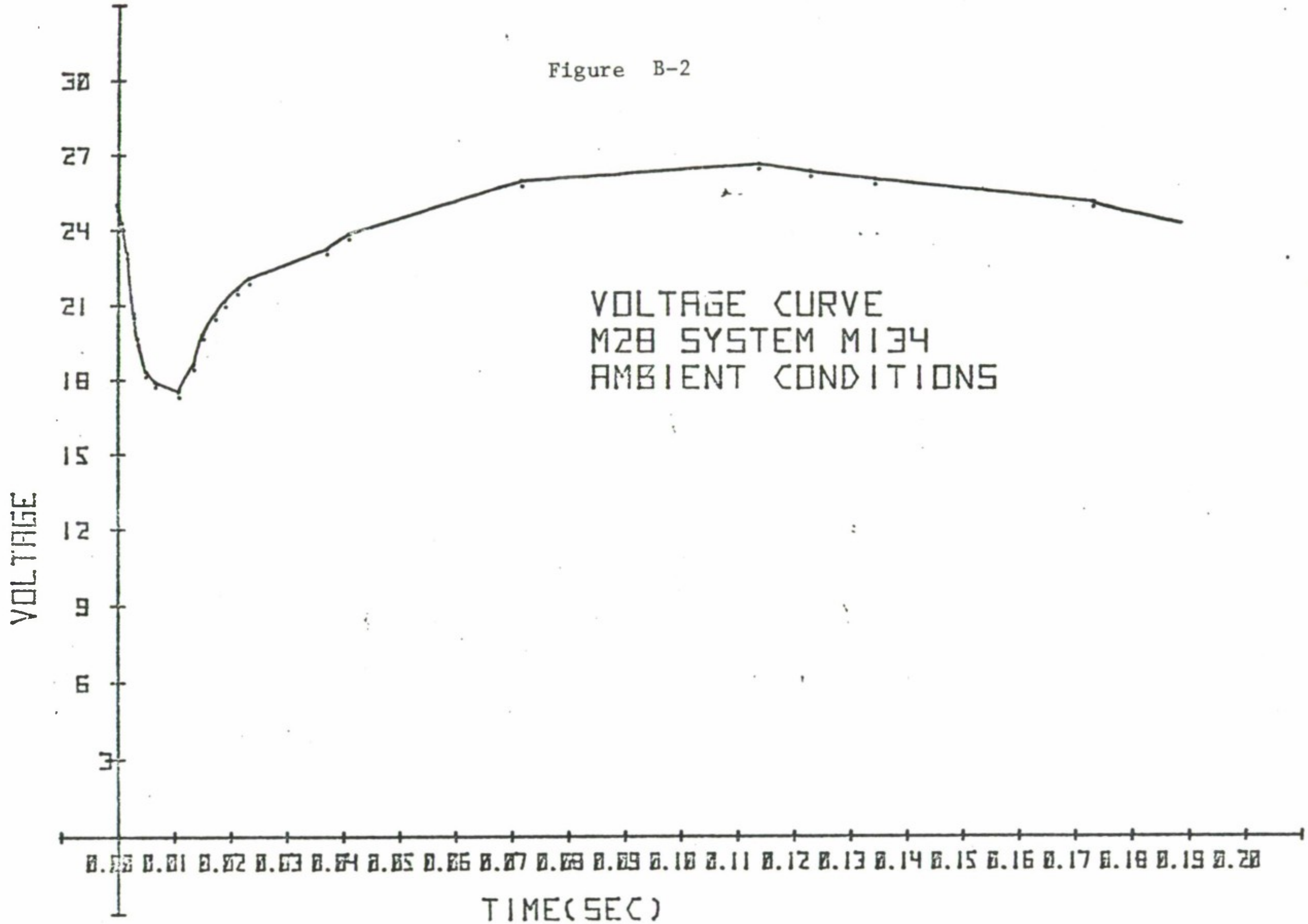

CURRENT CURVE
M28 SYSTEM M134
AMBIENT CONDITIONS
CURRENT(AMPS)
120
110
100
90
80
70
60
50
40
30
20
10
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20
TIME(SEC)

Figure B-1

Figure B-2


VOLTAGE CURVE
M28 SYSTEM M134
AMBIENT CONDITIONS
VOLTAGE
30
27
24
21
18
15
12
9
6
3
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20
TIME(SEC)

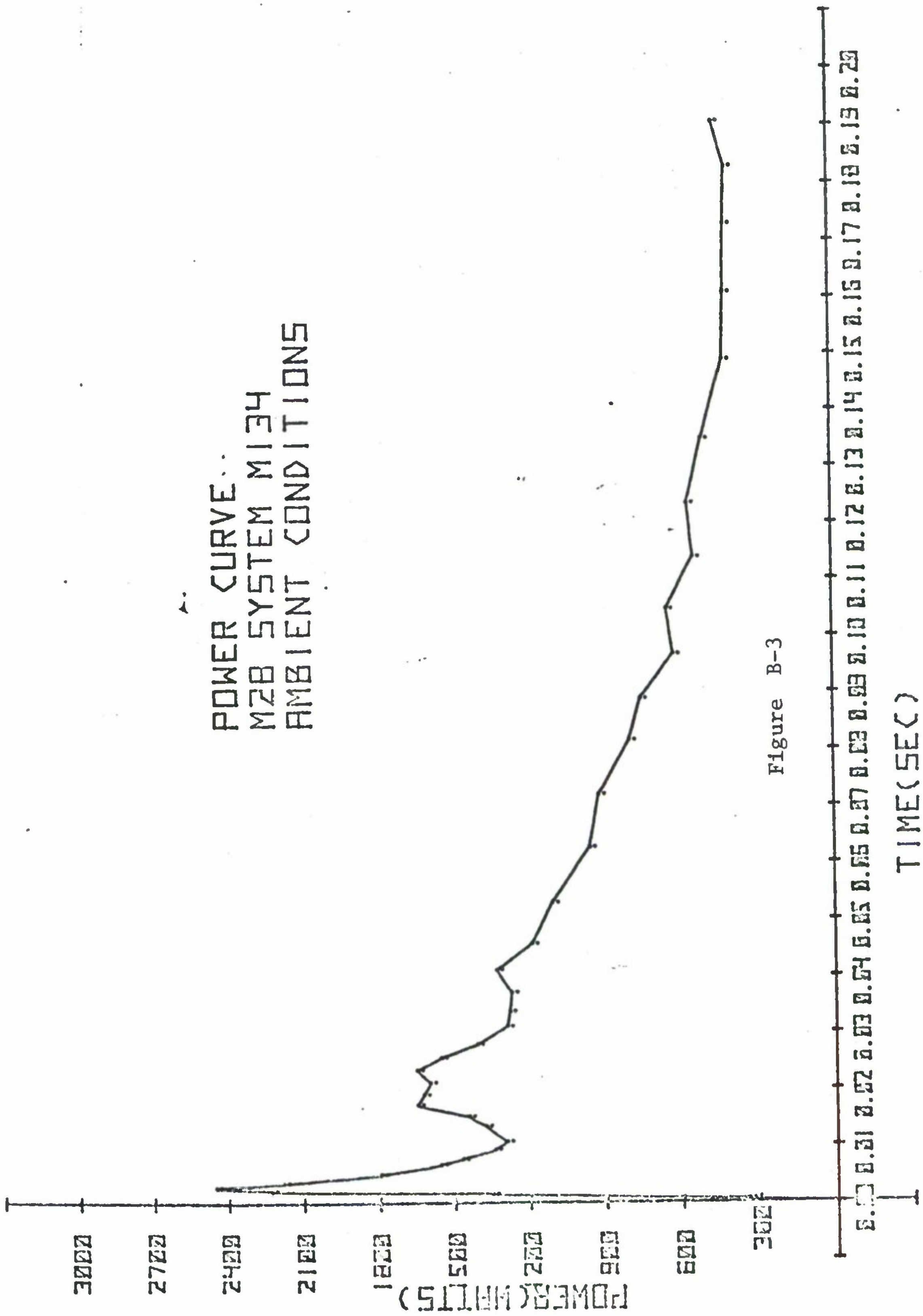
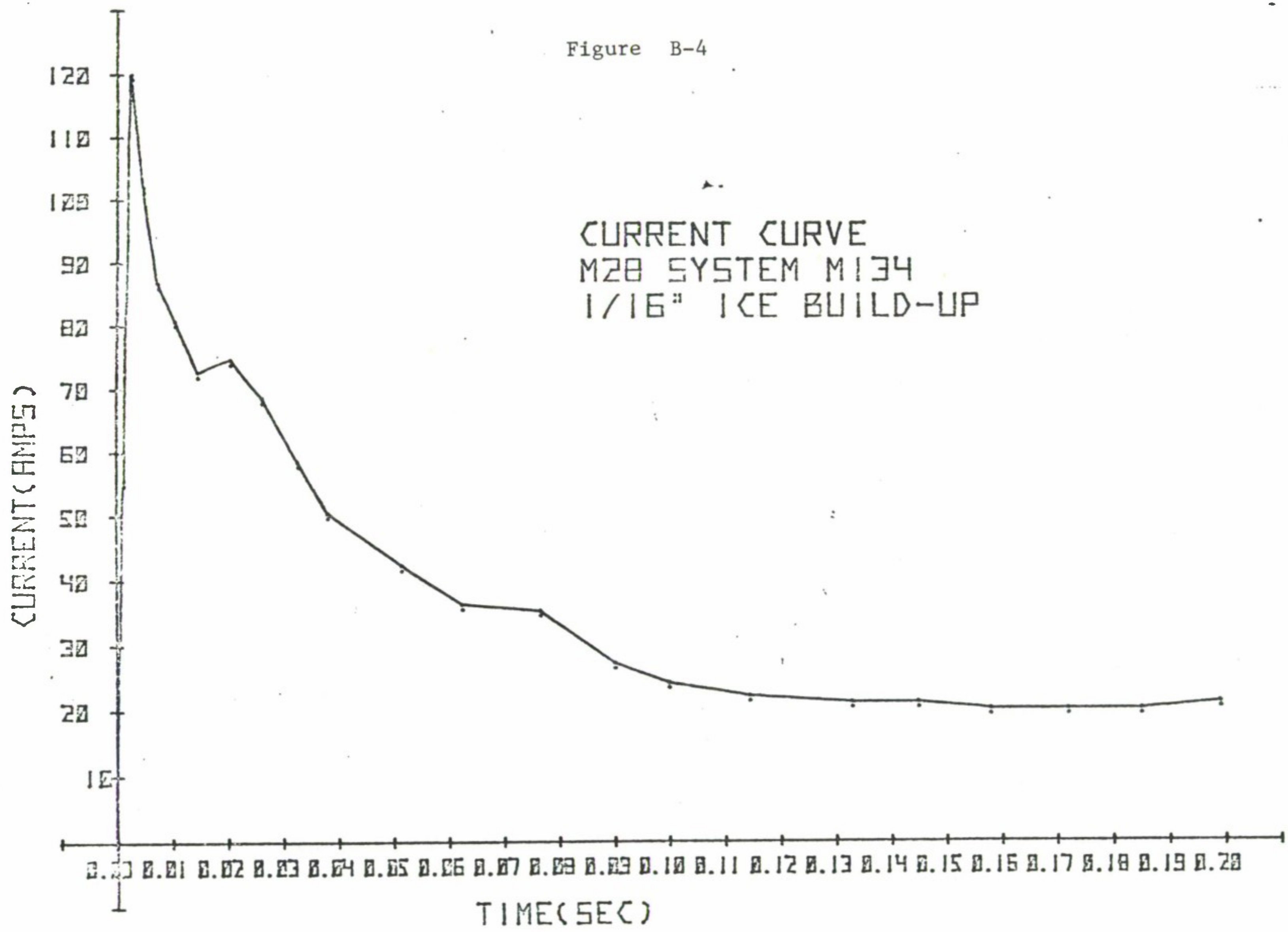

POWER CURVE
M2B SYSTEM M134
AMBIENT CONDITIONS
POWER(WATTS)
3000
2700
2400
2100
1800
1500
1200
900
600
300
TIME(SEC)

Figure B-3

Figure B-4


CURRENT CURVE
M28 SYSTEM M134
1/16" ICE BUILD-UP
CURRENT(AMPS)
TIME(SEC)
120
110
100
90
80
70
60
50
40
30
20
0.01 0.02 0.03 0.04 0.05 0.06 0.07
0.10 0.11 0.12 0.13 0.14 0.15
0.17 0.18 0.19 0.20

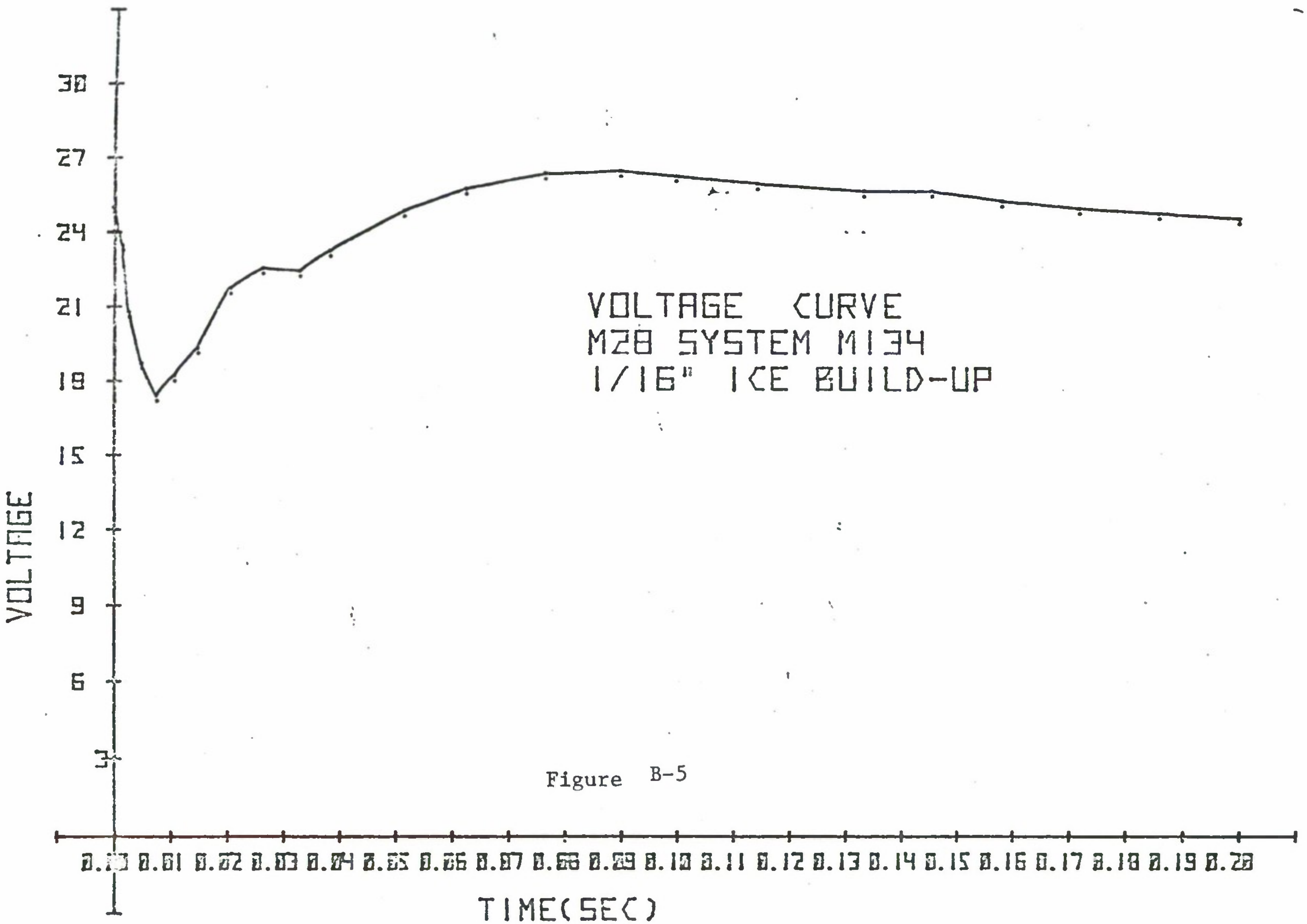
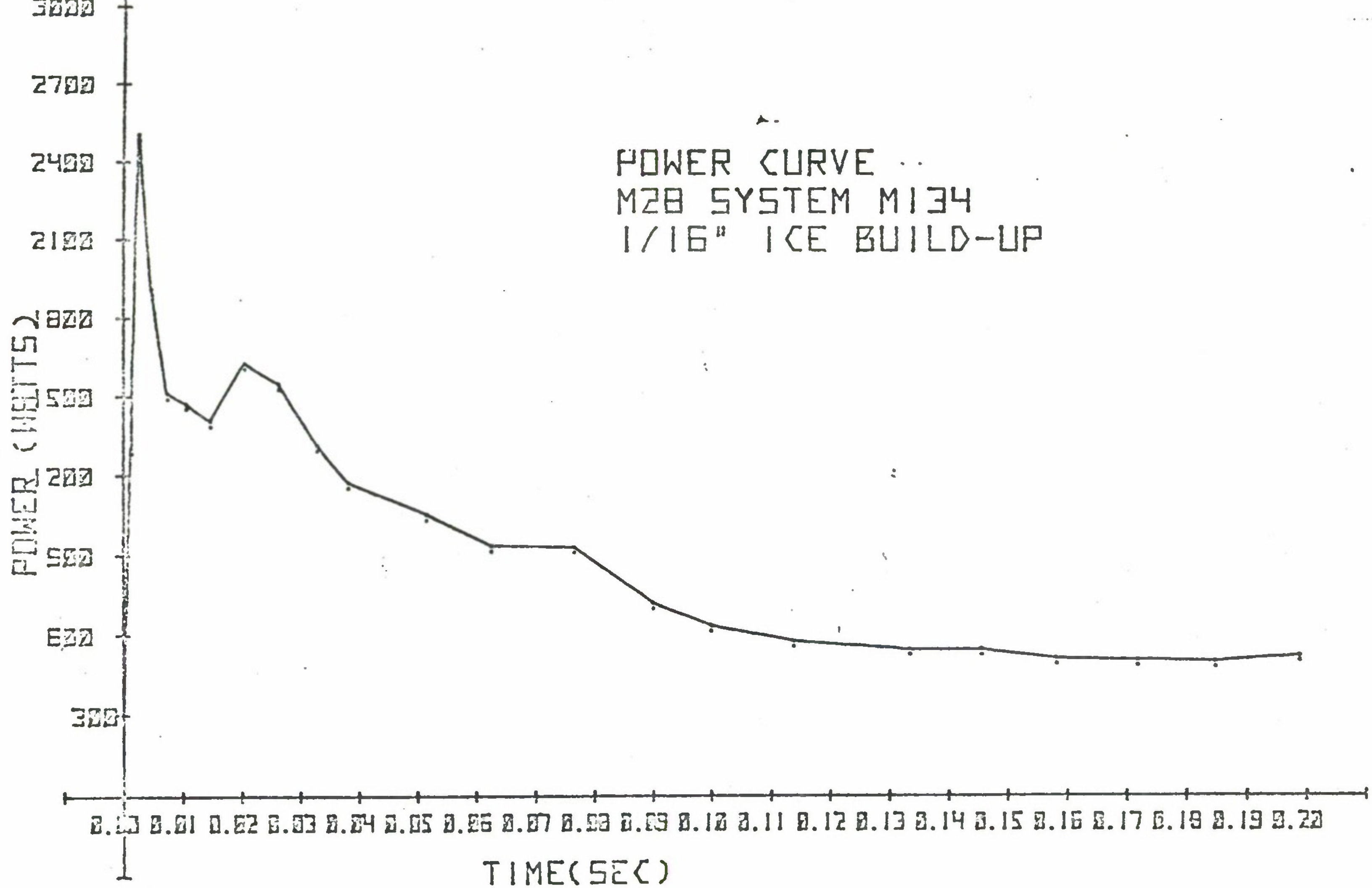

VOLTAGE CURVE
M28 SYSTEM M134
1/16" ICE BUILD-UP
VOLTAGE
30
27
24
21
18
15
12
9
6
3
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20
TIME(SEC)

Figure B-5

Figure B-6


POWER CURVE
M28 SYSTEM M134
1/16" ICE BUILD-UP
3000
2700
2400
2100
300
TIME(SEC)
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.19
0.20

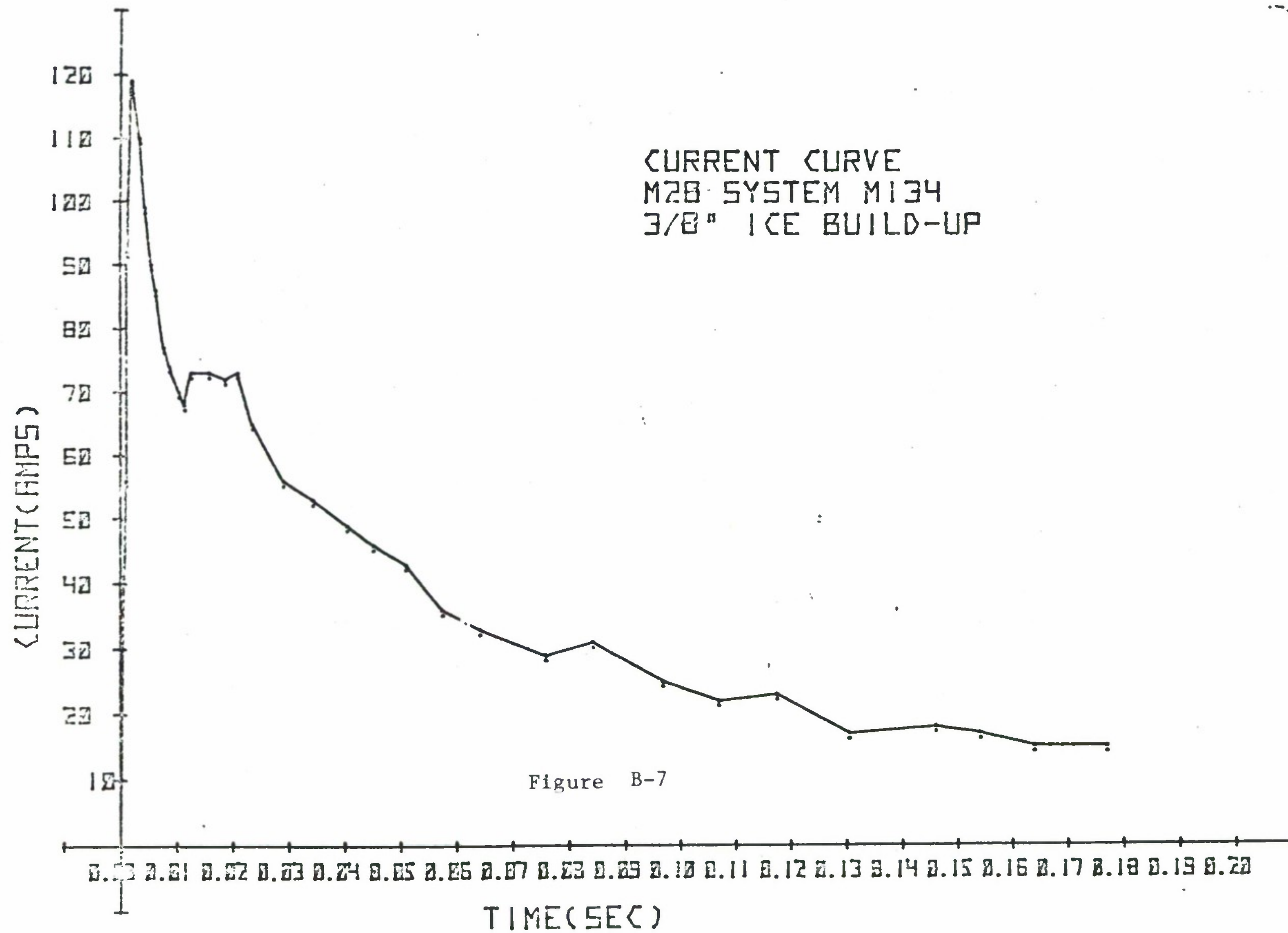
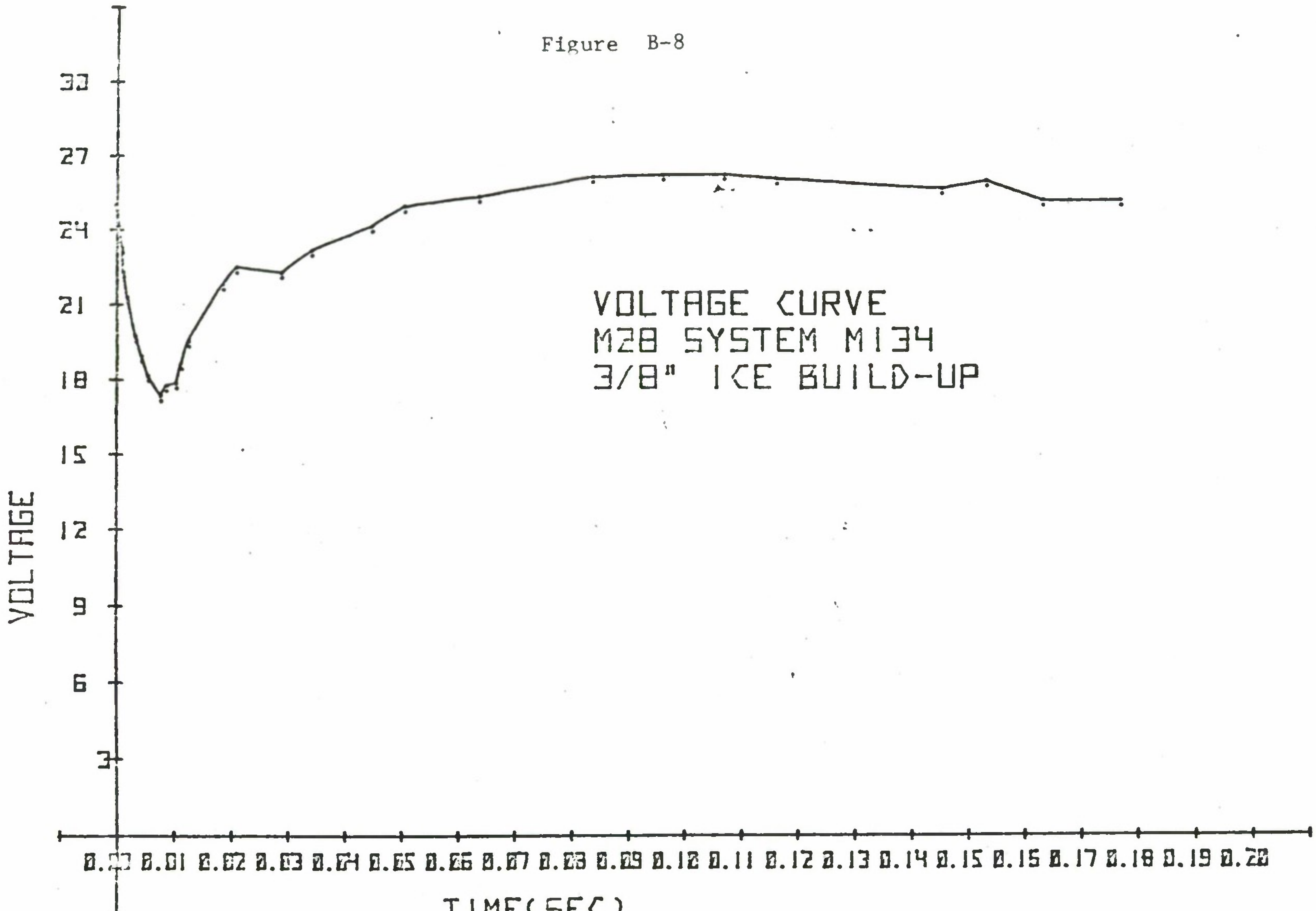

CURRENT CURVE
M28 SYSTEM M134
3/8" ICE BUILD-UP
120
110
100
90
80
70
60
50
40
30
20
10
CURRENT(AMPS)
0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20
TIME(SEC)

Figure B-7

Figure B-8


VOLTAGE CURVE
M28 SYSTEM M134
3/8" ICE BUILD-UP
VOLTAGE
33
27
24
21
18
15
12
9
6
3
TIME(SEC)
0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.15 0.17 0.18 0.19 0.20

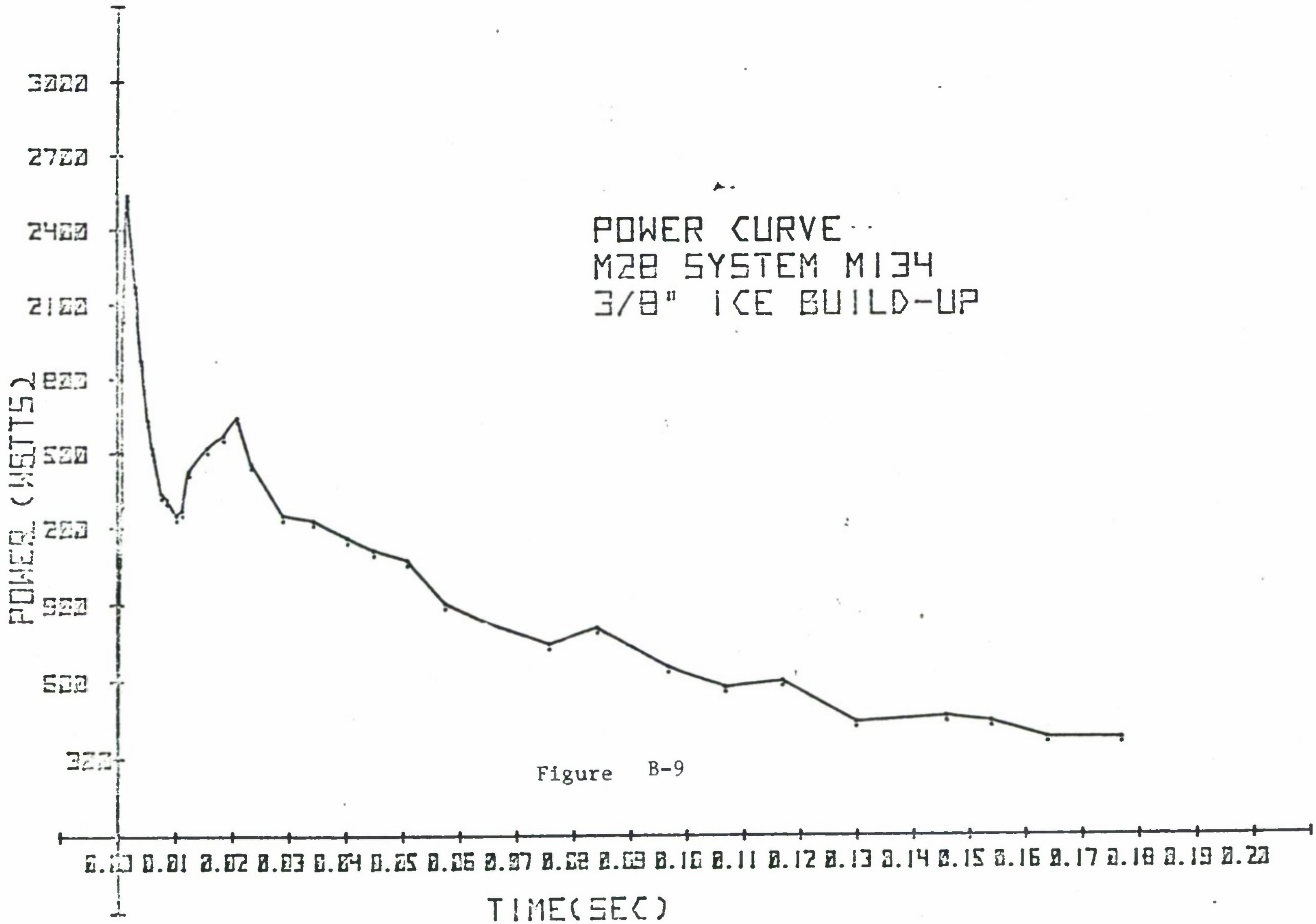
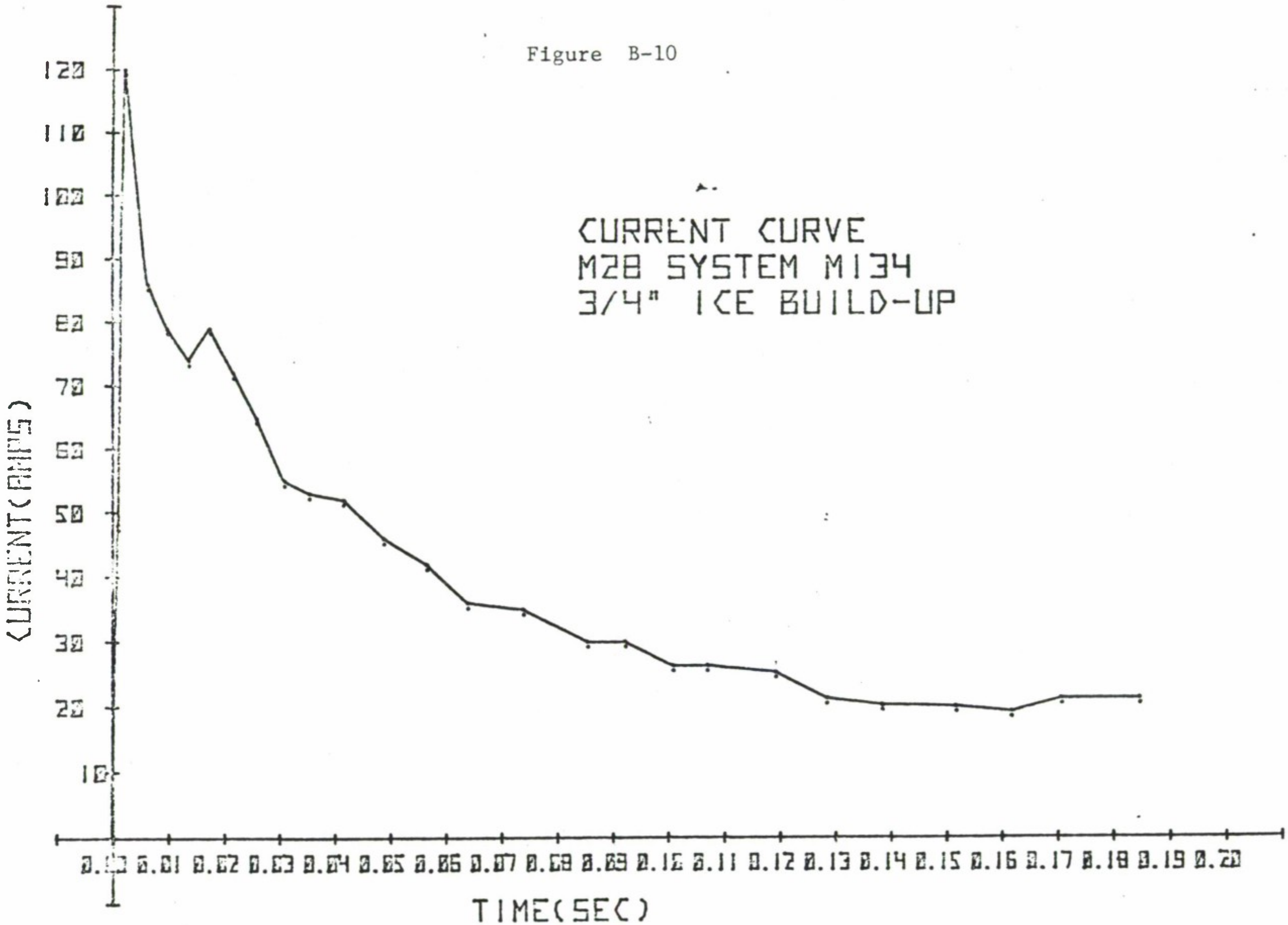

POWER CURVE
M28 SYSTEM M134
3/8" ICE BUILD-UP
POWER (WATTS)
TIME(SEC)
3000
2700
2400
2100
0.01
0.02
0.03
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19

Figure B-9

Figure B-10



CURRENT CURVE
M28 SYSTEM M134
3/4" ICE BUILD-UP
120
110
100
90
80
70
60
50
40
30
20
10
(CURRENT(AMPS)
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20
TIME(SEC)

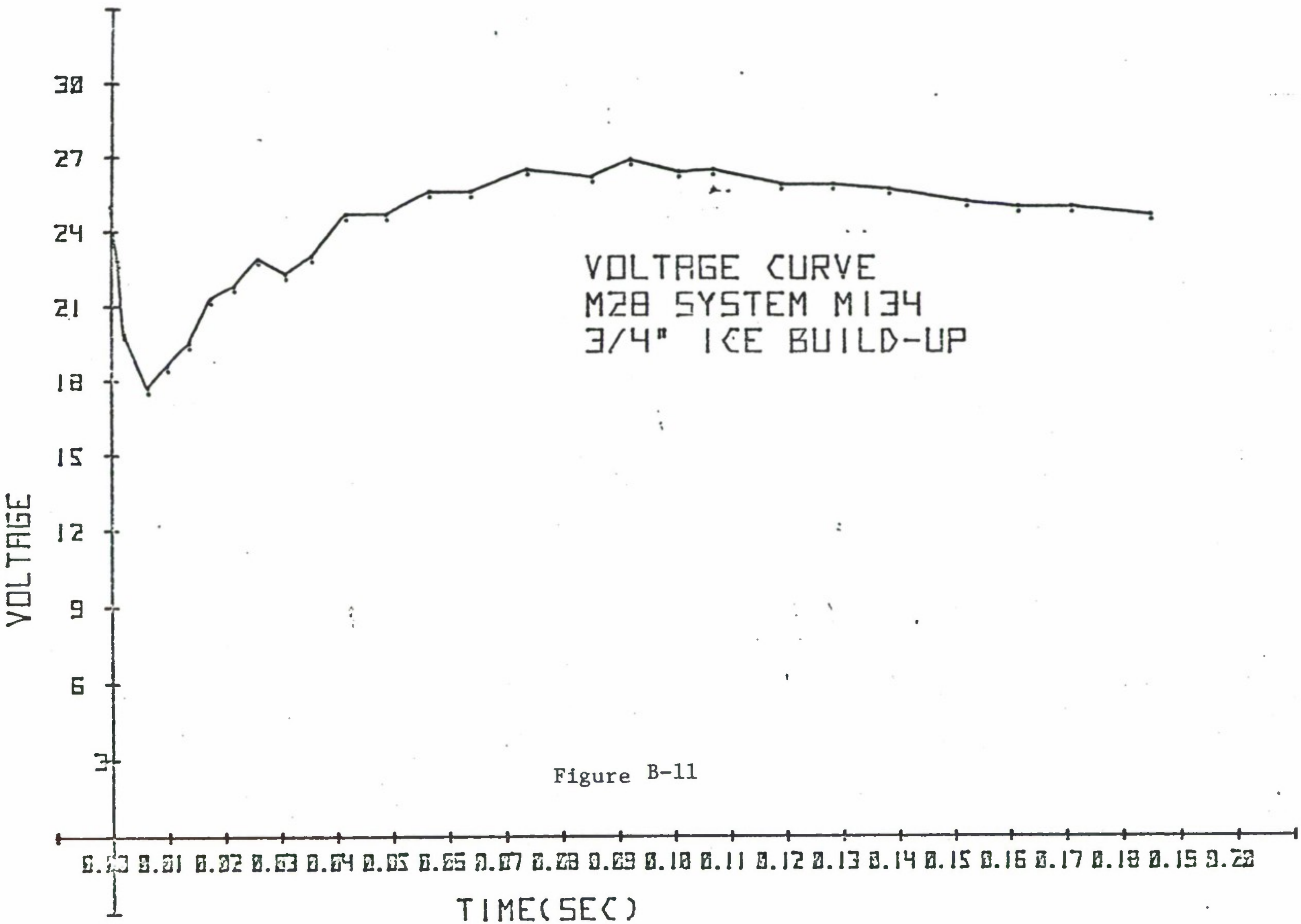
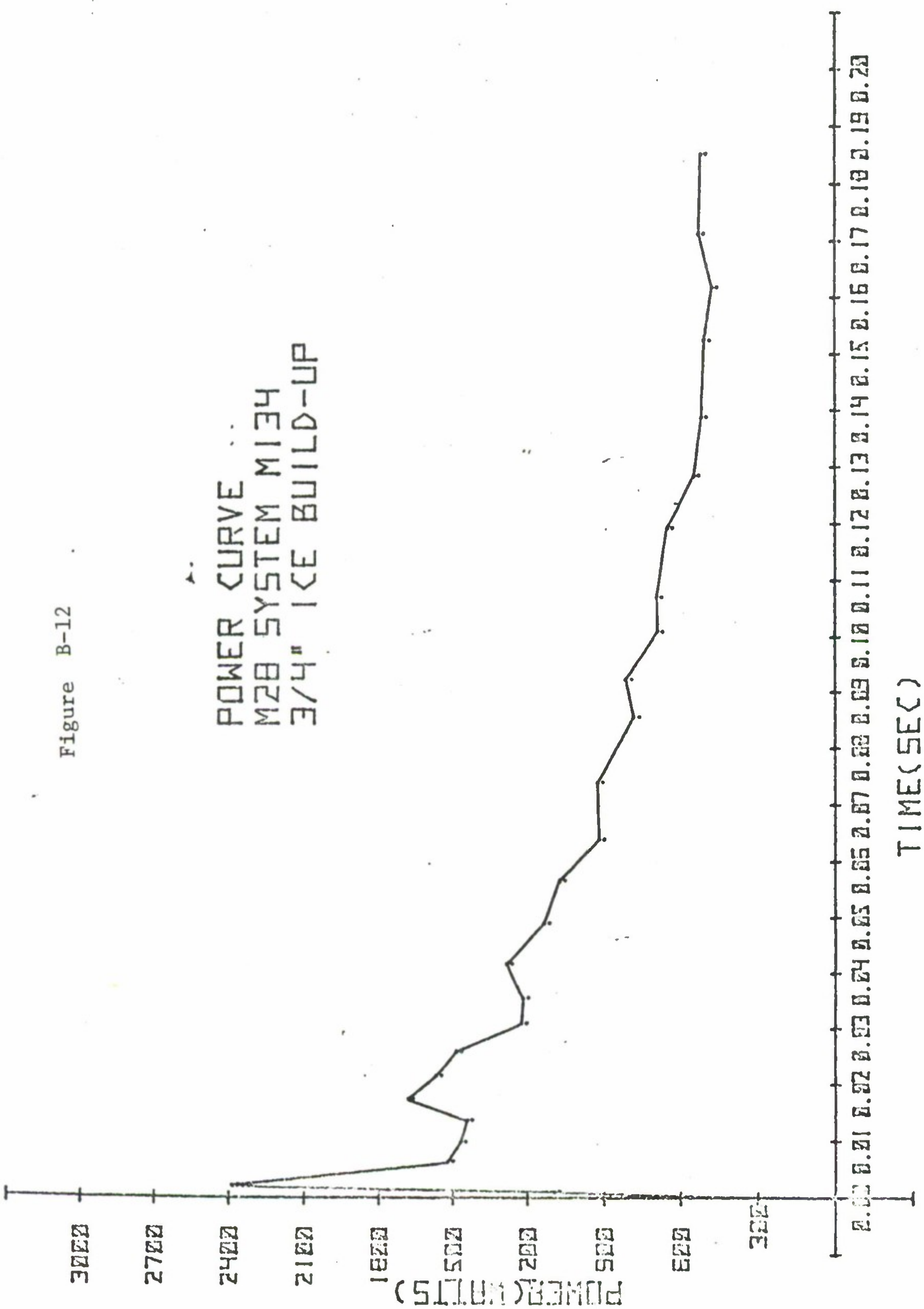

VOLTAGE CURVE
M28 SYSTEM M134
3/4" ICE BUILD-UP
VOLTAGE
30
27
24
21
18
15
12
9
6
TIME(SEC)
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20

Figure B-11

Figure B-12


POWER CURVE
M28 SYSTEM M134
3/4" ICE BUILD-UP
POWER(WATTS)
3000
2700
2400
2100
1800
1500
1200
900
600
300
TIME(SEC)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19
0.20

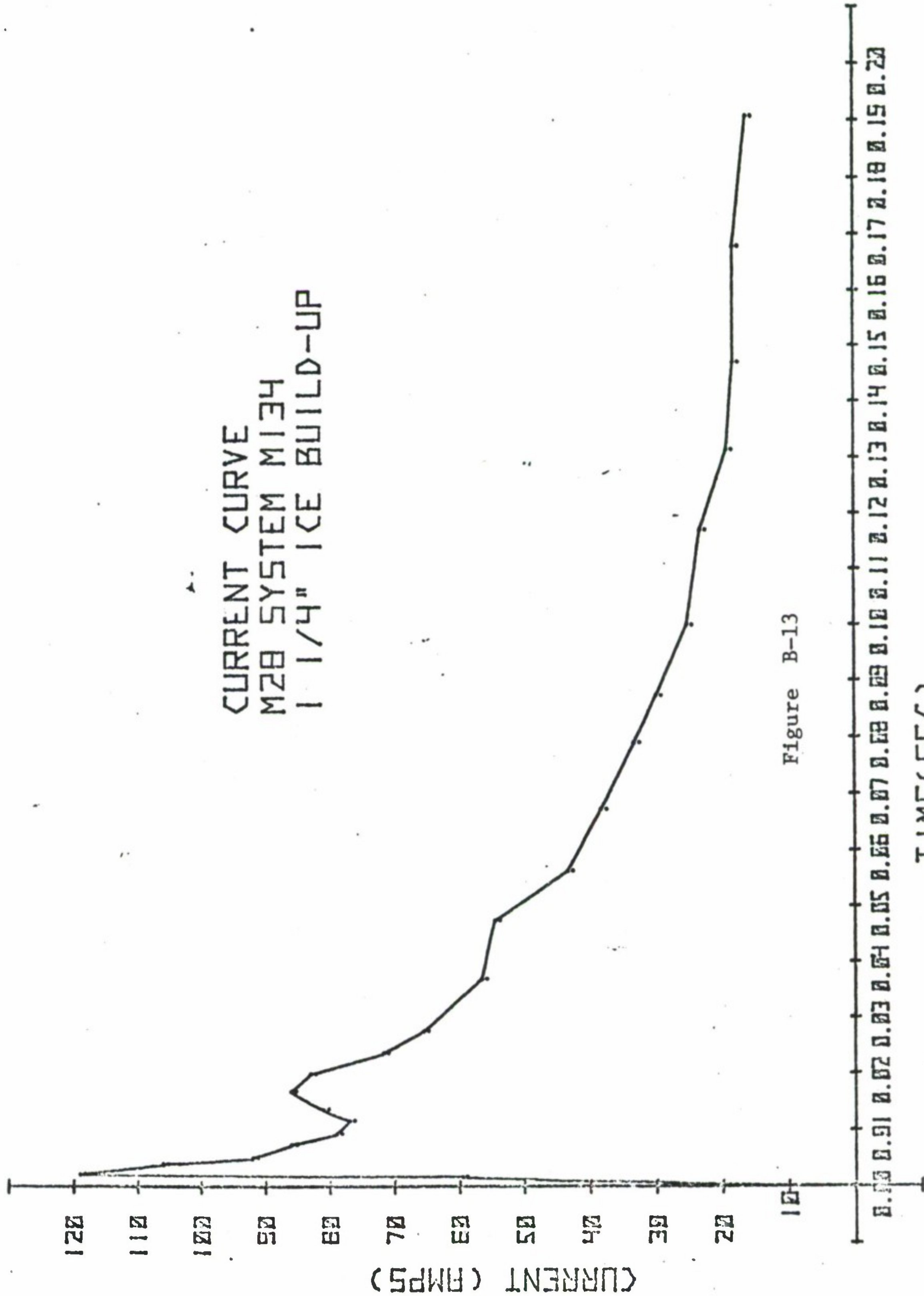
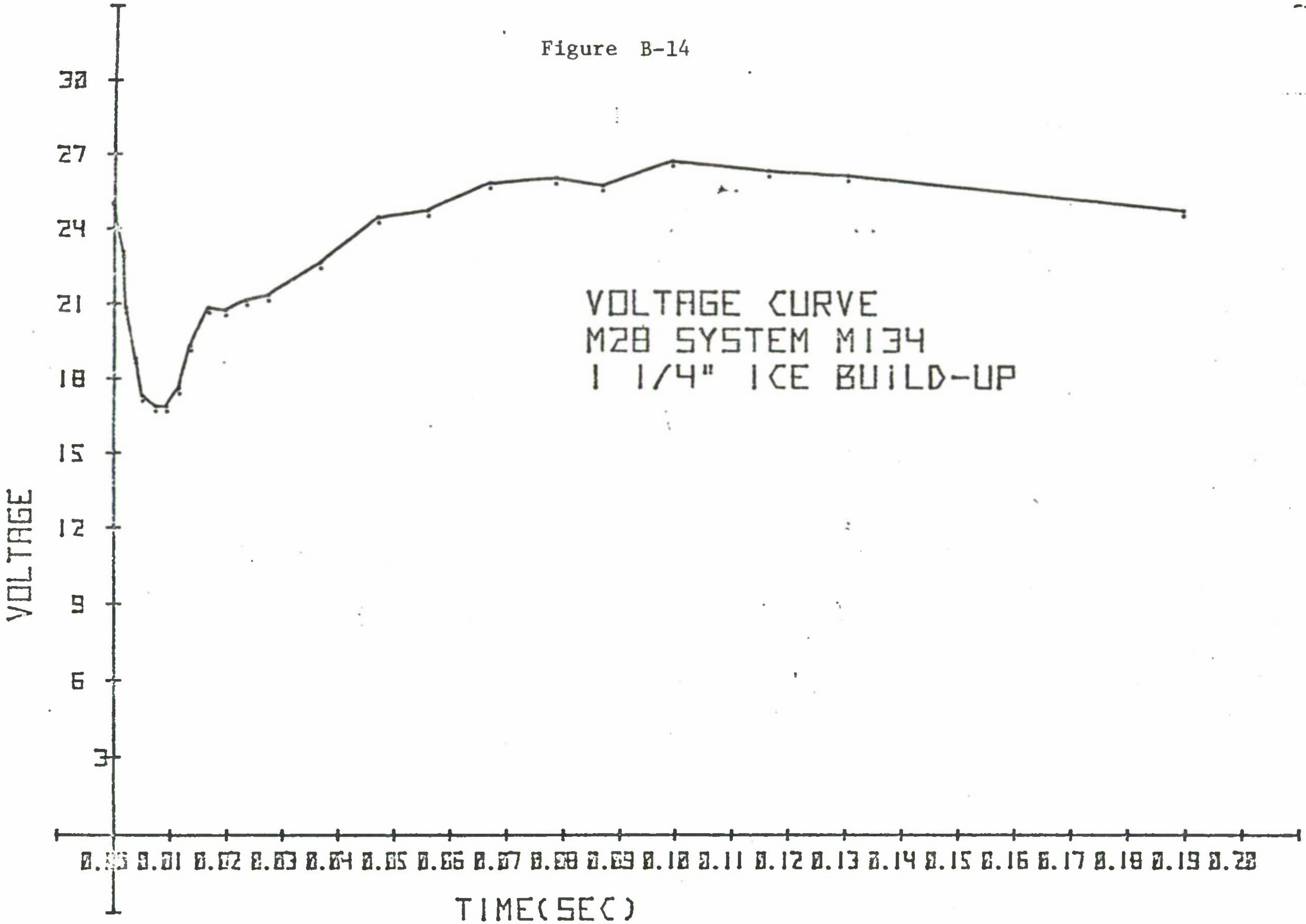

CURRENT CURVE
M20 SYSTEM M134
1 1/4" ICE BUILD-UP
CURRENT (AMPS)
TIME(SEC)

Figure B-13

Figure B-14


VOLTAGE CURVE
M28 SYSTEM M134
1 1/4" ICE BUILD-UP
VOLTAGE
30
27
24
21
18
15
12
9
6
3
TIME(SEC)
0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20

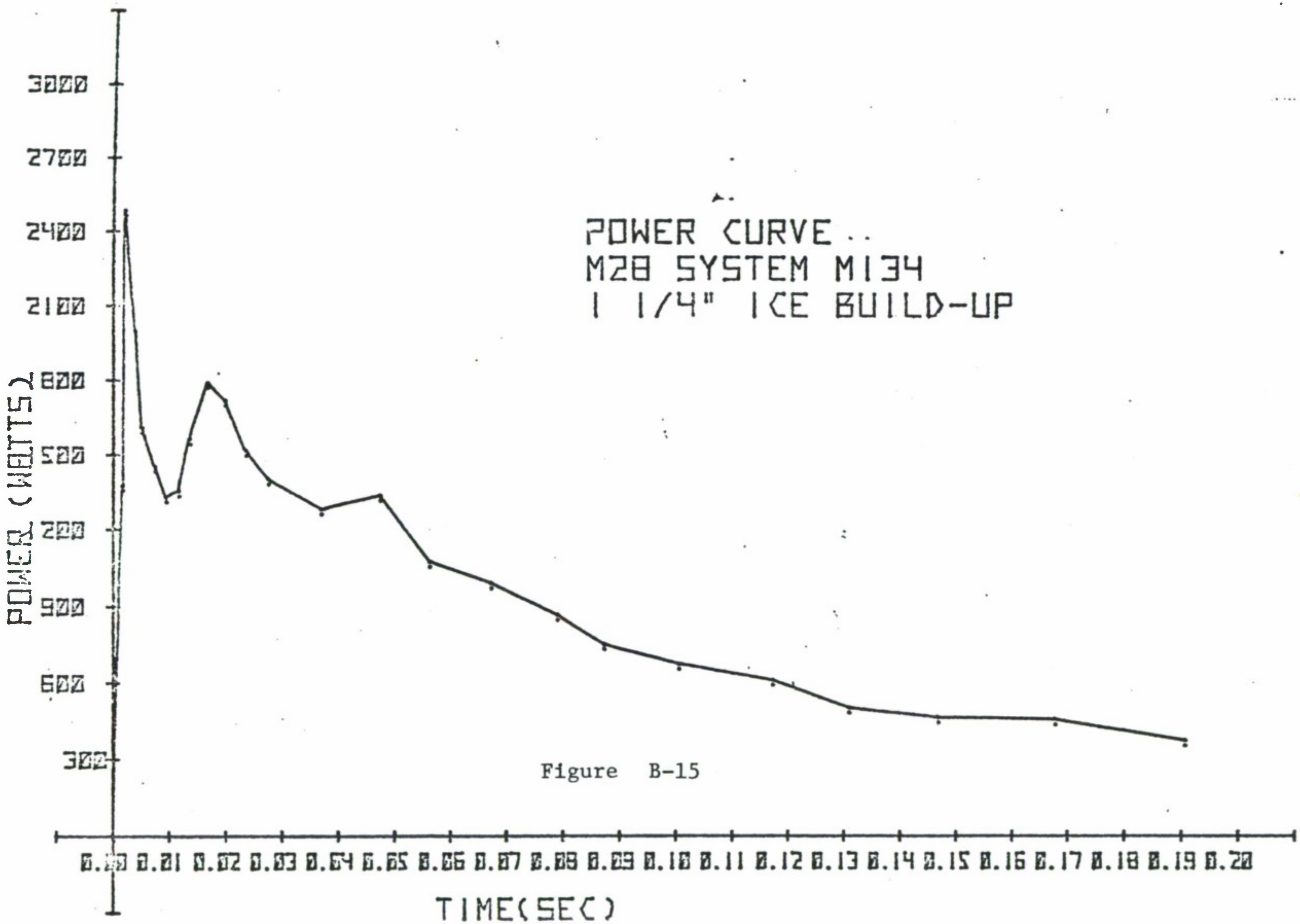

POWER CURVE
M28 SYSTEM M134
1 1/4" ICE BUILD-UP
POWER (WATTS)
3000
2700
2400
2100
1800
1500
1200
900
600
300
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20
TIME(SEC)

Figure B-15

Blank

APPENDIX C

PHASE III DATA

7.62mm, M134 Gun, Clear Mode,

With Flash Suppressor

TABLE C-1

M134 Gun With Flash Suppressor

Rds Fired	Type of Fire	Rate of Fire, spm	Airflow, ft/min.	Ice Accum.	Temp. of Room	Operating Voltage
30	Auto	2093	1200	N/A	Ambient	25V
30	Auto	1847	1200	1/16"	0°F	25V
30	Auto	2248	1200	3/8"	0°F	25V
30	Auto	2074	1200	3/4"	0°F	25V
30	Auto	2668	1200	1 1/4"	0°F	25V

TABLE C-2

M134 Gun With Flash Suppressor

Bore Measurements Before Icing Test

Distance From Breech	Barrels[a] #1	#2	#3	#4	#5	#6
3"	.3020	.3013	.3010	.3010	.3008	.3008
6"	.2998	.3000	.3000	.3015	.3008	.3005
9"	.2995	.3010	.3000	.3010	.3005	.3005
12"	.2990	.2995	.3000	.3005	.3000	.3003
15"	.2990	.3000	.3000	.3005	.3000	.3000
18"	.2990	.3000	.2995	.3002	.2998	.3000
21"	.2990	.2995	.2990	.3000	.2995	.3000

Note: a. Drawing dimension for the bore is .2995 dia +.0015.

TABLE C-3

M134 Gun With Flash Suppressor

Bore Measurements After Icing Test

Distance From Breech	Barrels[a] #1	#2	#3	#4	#5	#6
3"	.3020	.3010	.3010	.3010	.3008	.3008
6"	.3000	.2995	.3000	.3015	.3008	.3005
9"	.2998	.3010	.3000	.3010	.3005	.3005
12"	.2995	.2995	.3000	.3005	.3000	.3005
15"	.2995	.3000	.3000	.3005	.3000	.3000
18"	.2990	.2995	.2995	.3000	.2998	.3000
21"	.2990	.2995	.2990	.3000	.2995	.3000

Note: a. Drawing dimension for the bore is .2995 dia +.0015.

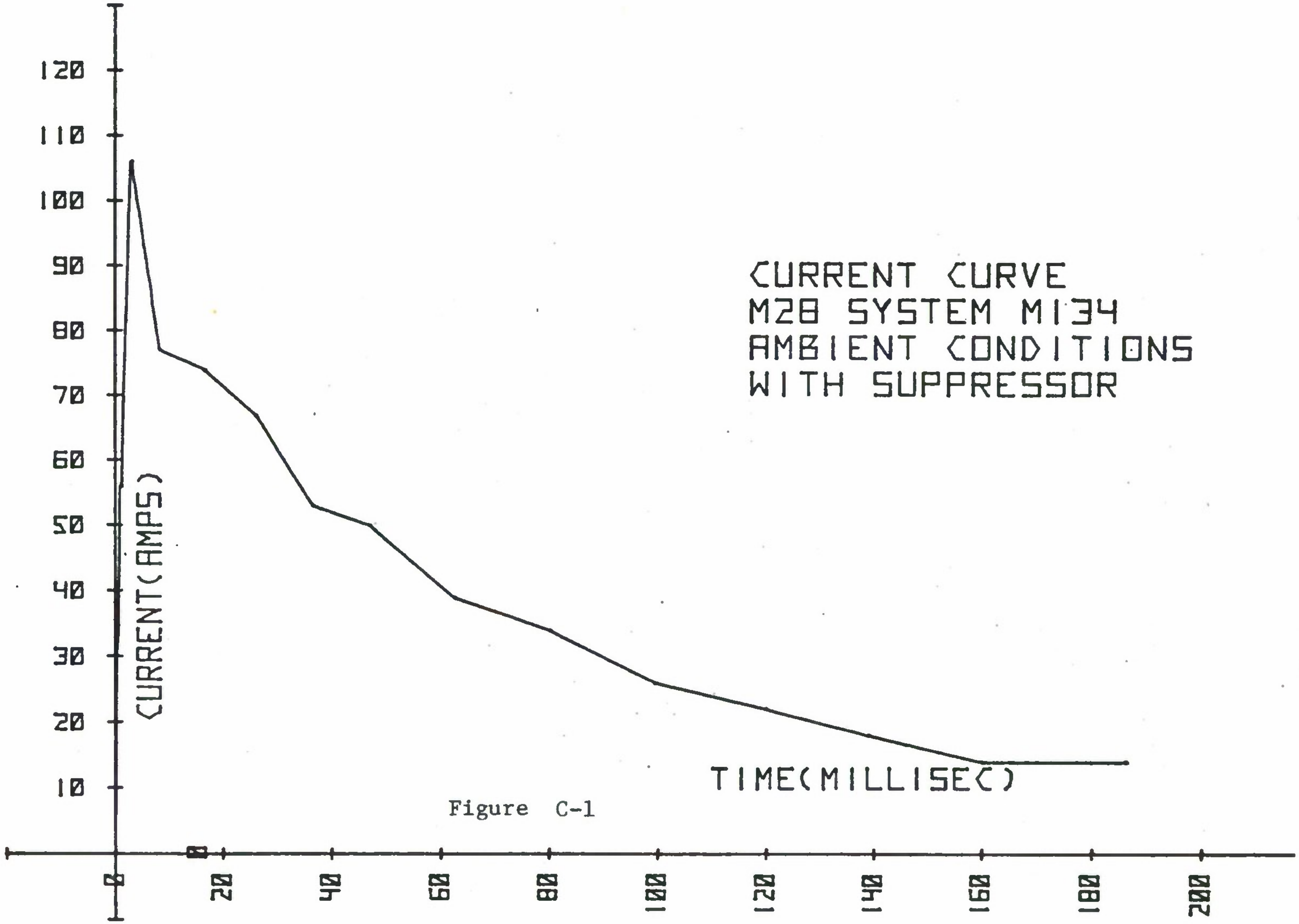

CURRENT CURVE
M28 SYSTEM M134
AMBIENT CONDITIONS
WITH SUPPRESSOR
CURRENT(AMPS)
TIME(MILLISEC)
120
110
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200

Figure C-1

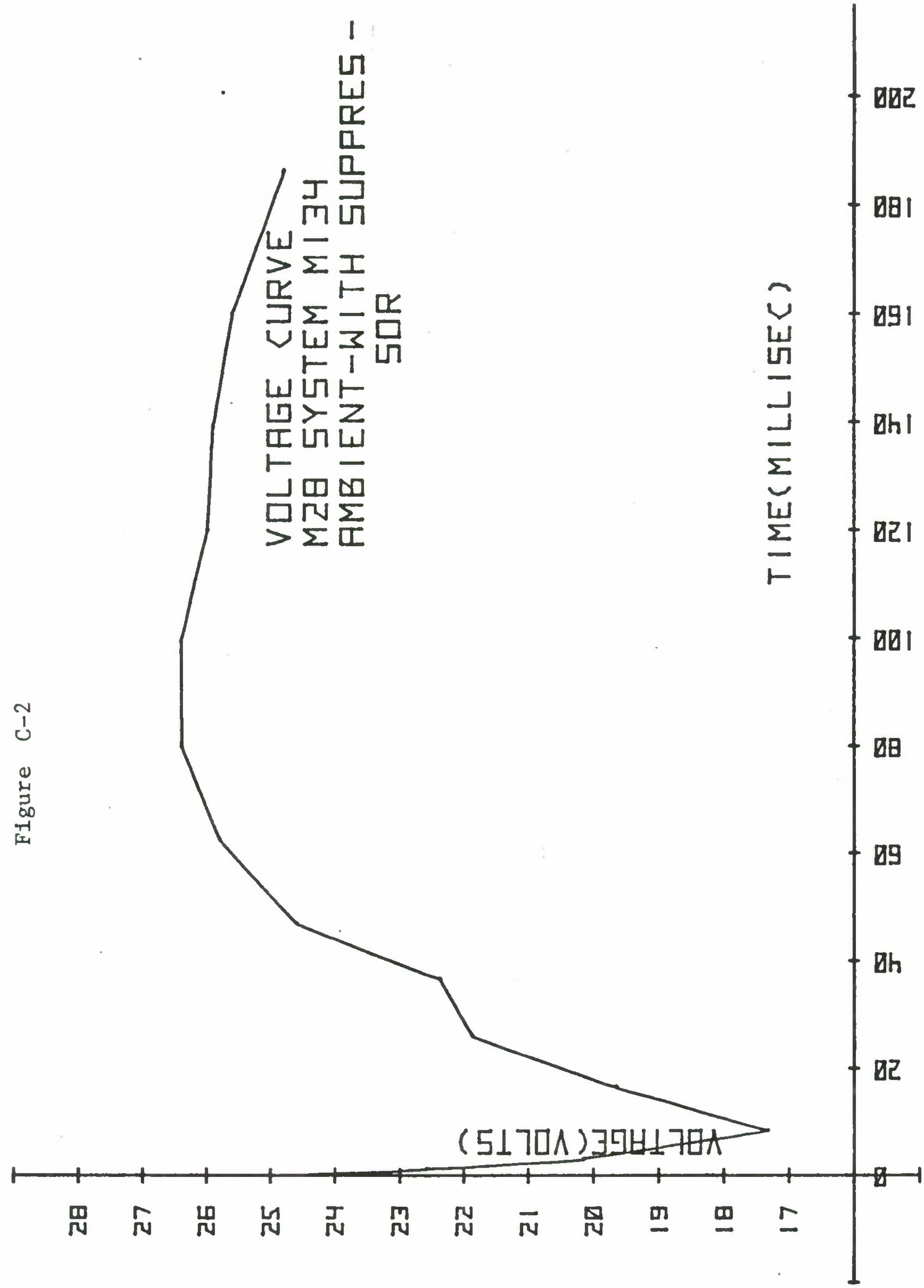

VOLTAGE CURVE
M28 SYSTEM M134
AMBIENT-WITH SUPPRES-
SOR
TIME(MILLISEC)
VOLTAGE(VOLTS)
0
20
40
60
80
100
120
140
160
180
200
17
18
19
20
21
22
23
24
25
26
27
28

Figure C-2

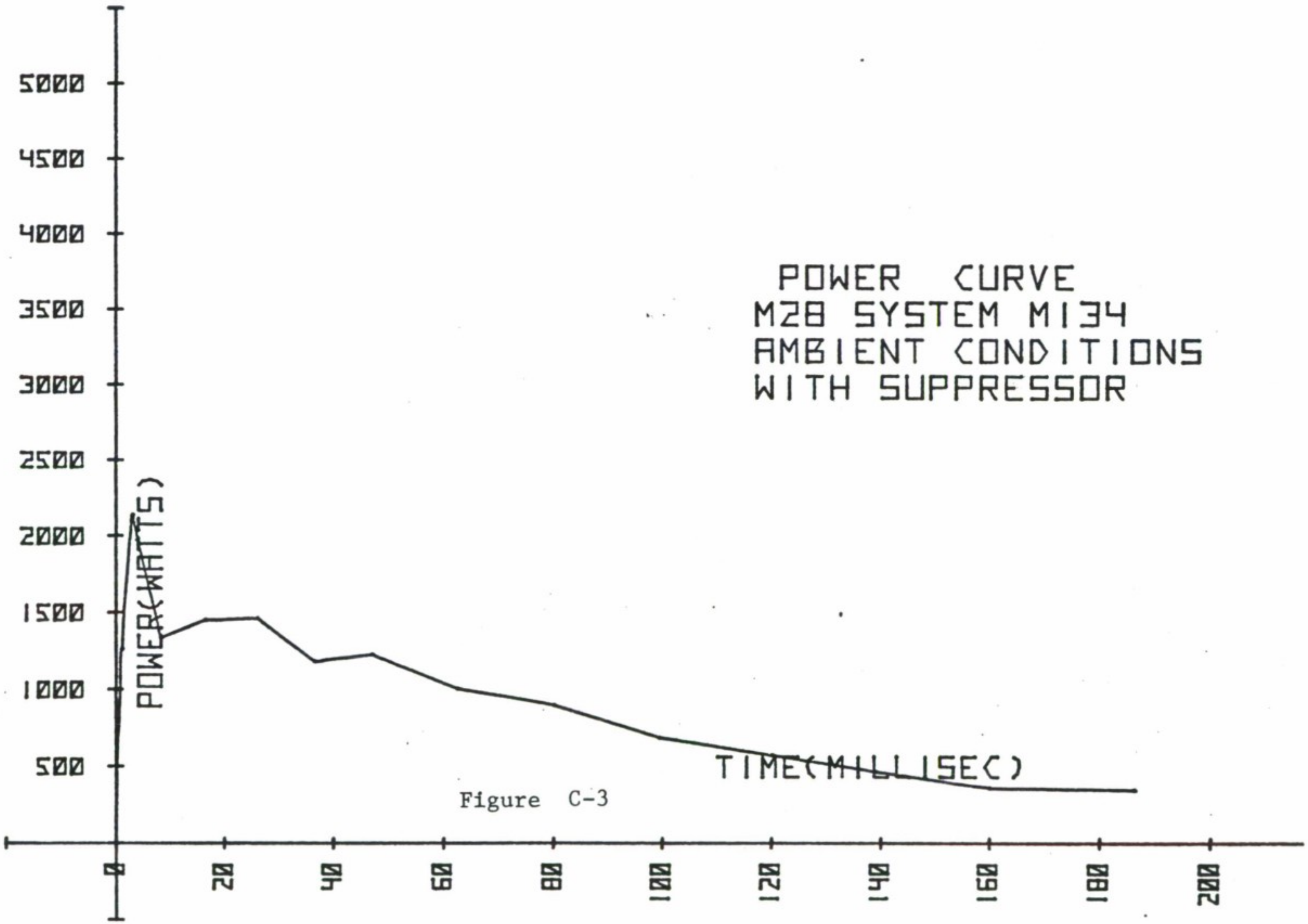
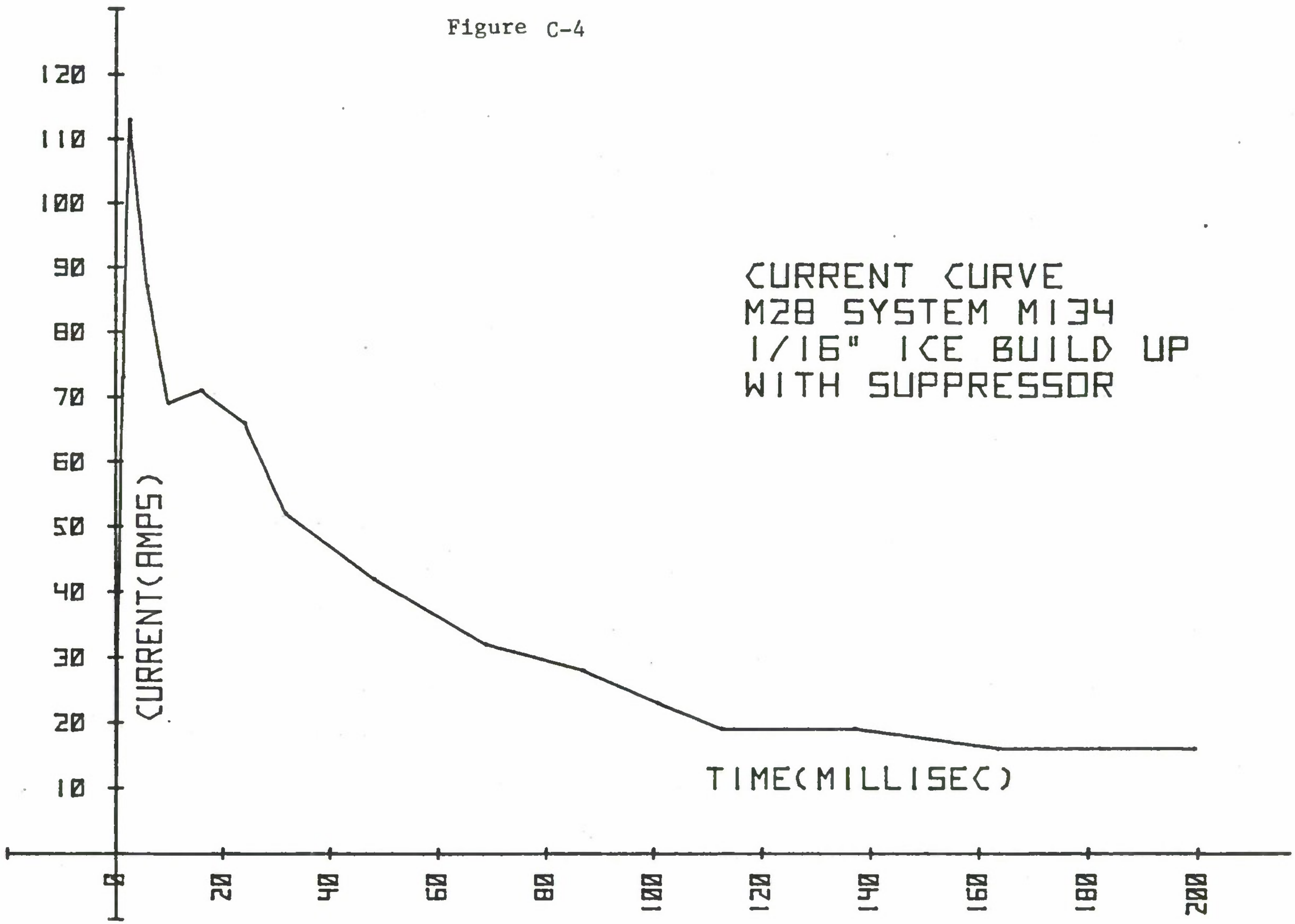

POWER CURVE
M28 SYSTEM M134
AMBIENT CONDITIONS
WITH SUPPRESSOR
POWER(WATTS)
TIME(MILLISEC)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
100
120
140
160
180
200

Figure C-3

Figure C-4


CURRENT CURVE
M28 SYSTEM M134
1/16" ICE BUILD UP
WITH SUPPRESSOR
CURRENT(AMPS)
TIME(MILLISEC)
120
110
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200

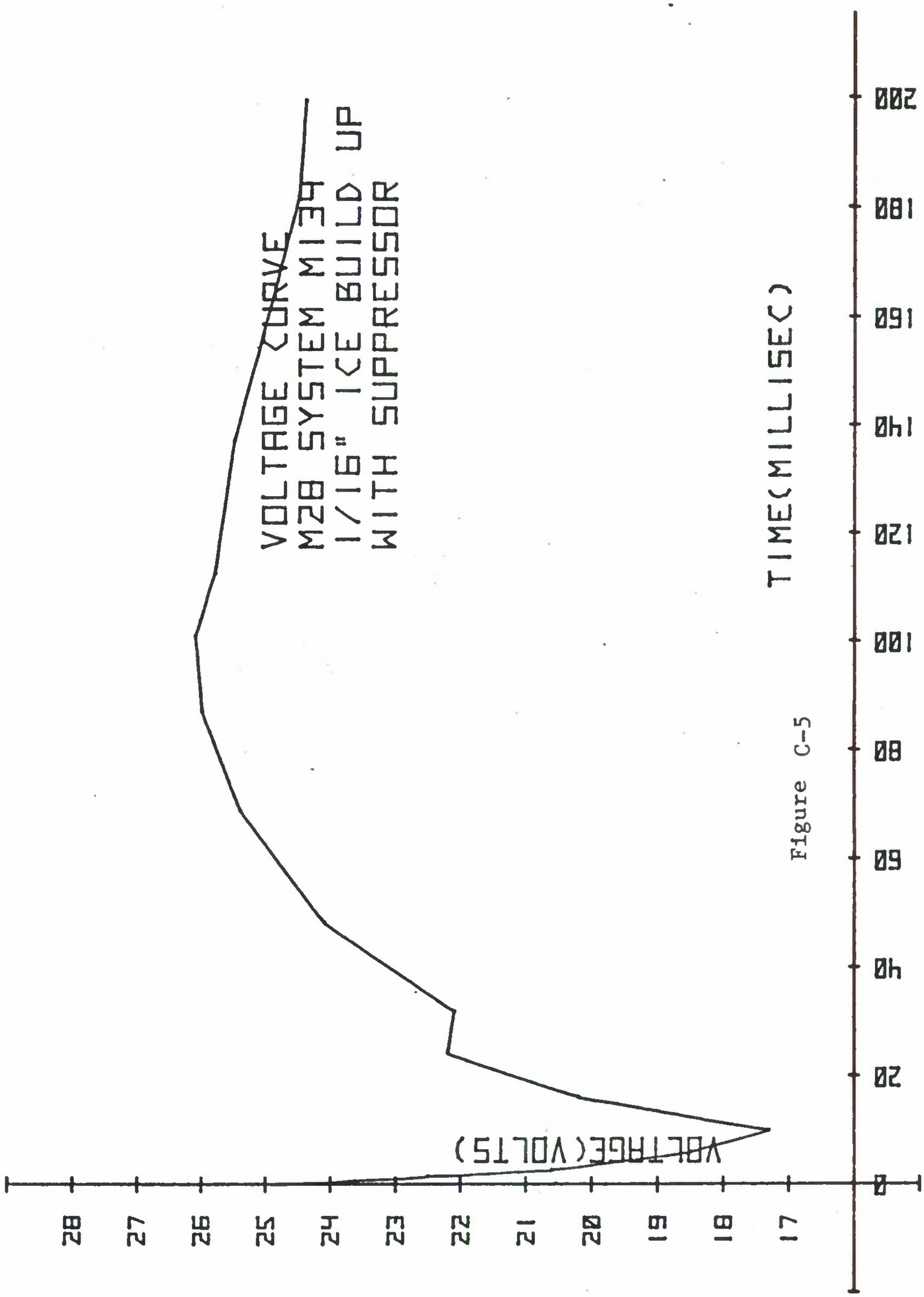
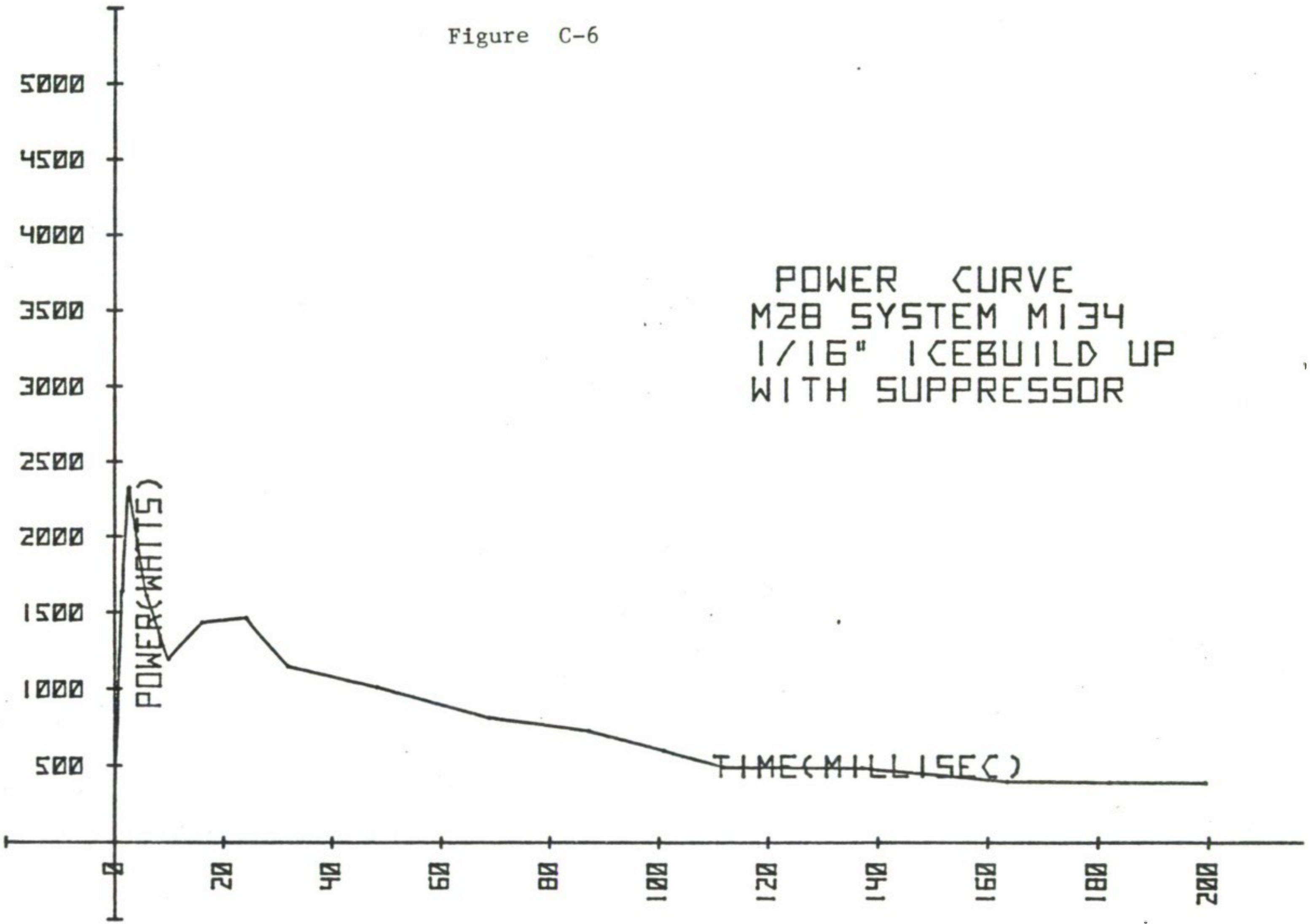

VOLTAGE CURVE
M28 SYSTEM M134
1/16" ICE BUILD UP
WITH SUPPRESSOR
TIME(MILLISEC)
VOLTAGE(VOLTS)
0
20
40
60
80
100
120
140
160
180
200
17
18
19
20
21
22
23
24
25
26
27
28

Figure C-5

Figure C-6


POWER CURVE
M28 SYSTEM M134
1/16" ICEBUILD UP
WITH SUPPRESSOR
POWER(WATTS)
TIME(MILLISEC)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
100
120
140
160
180
200

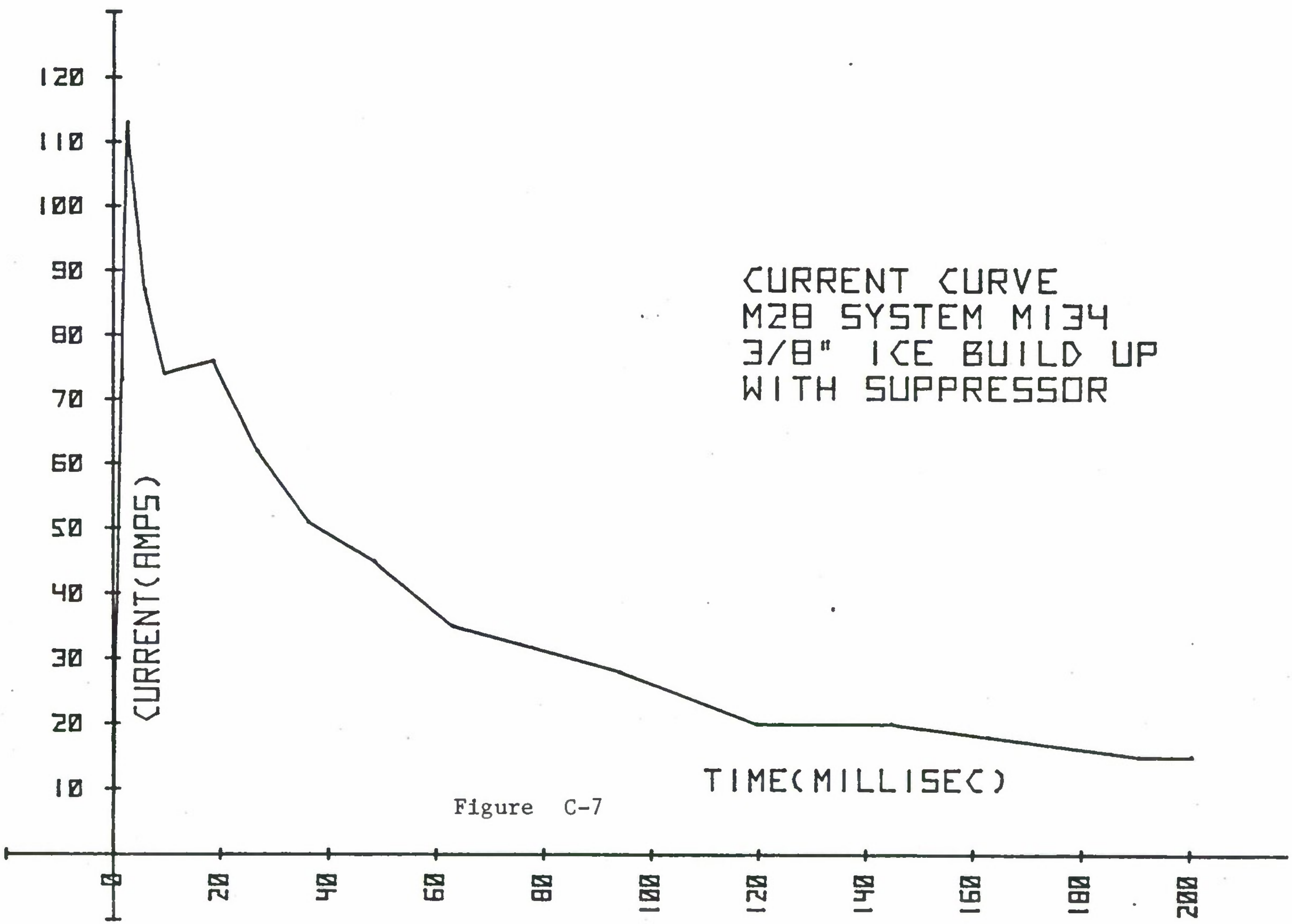
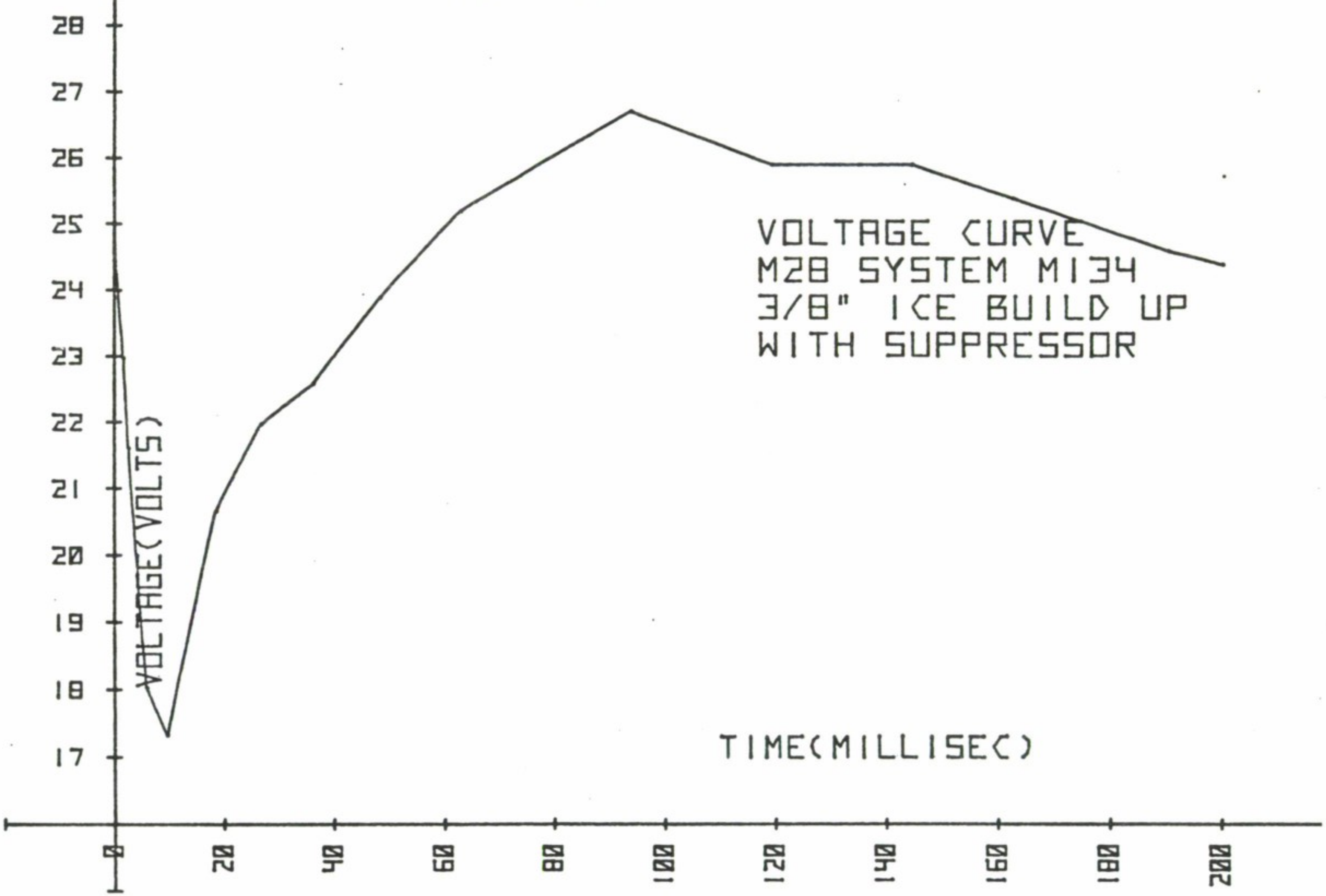

CURRENT CURVE
M28 SYSTEM M134
3/8" ICE BUILD UP
WITH SUPPRESSOR
CURRENT(AMPS)
TIME(MILLISEC)
120
110
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200

Figure C-7

Figure C-8



VOLTAGE CURVE
M28 SYSTEM M134
3/8" ICE BUILD UP
WITH SUPPRESSOR
VOLTAGE(VOLTS)
TIME(MILLISEC)
28
27
26
25
24
23
22
21
20
19
18
17
0
20
40
60
80
100
120
140
160
180
200

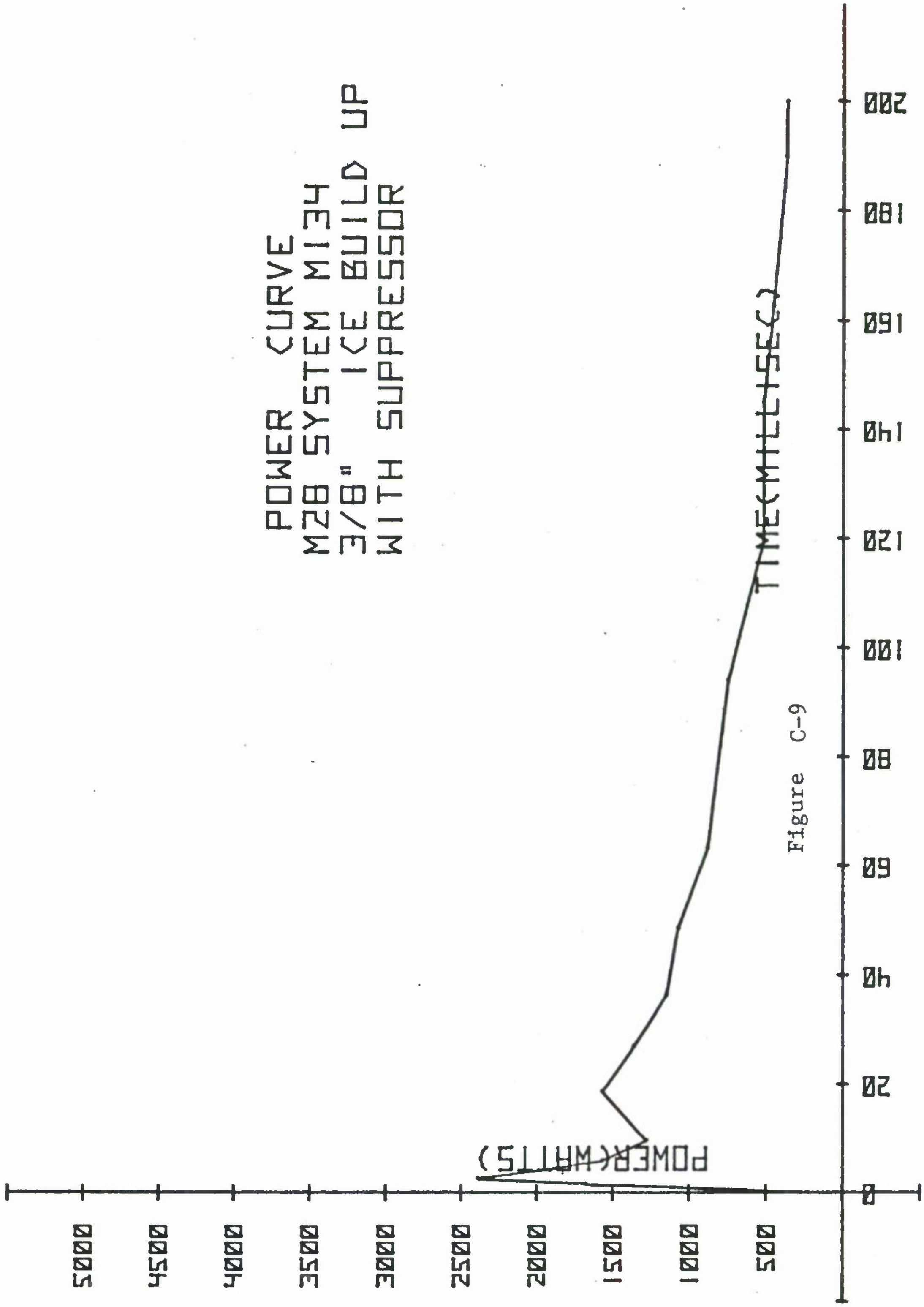
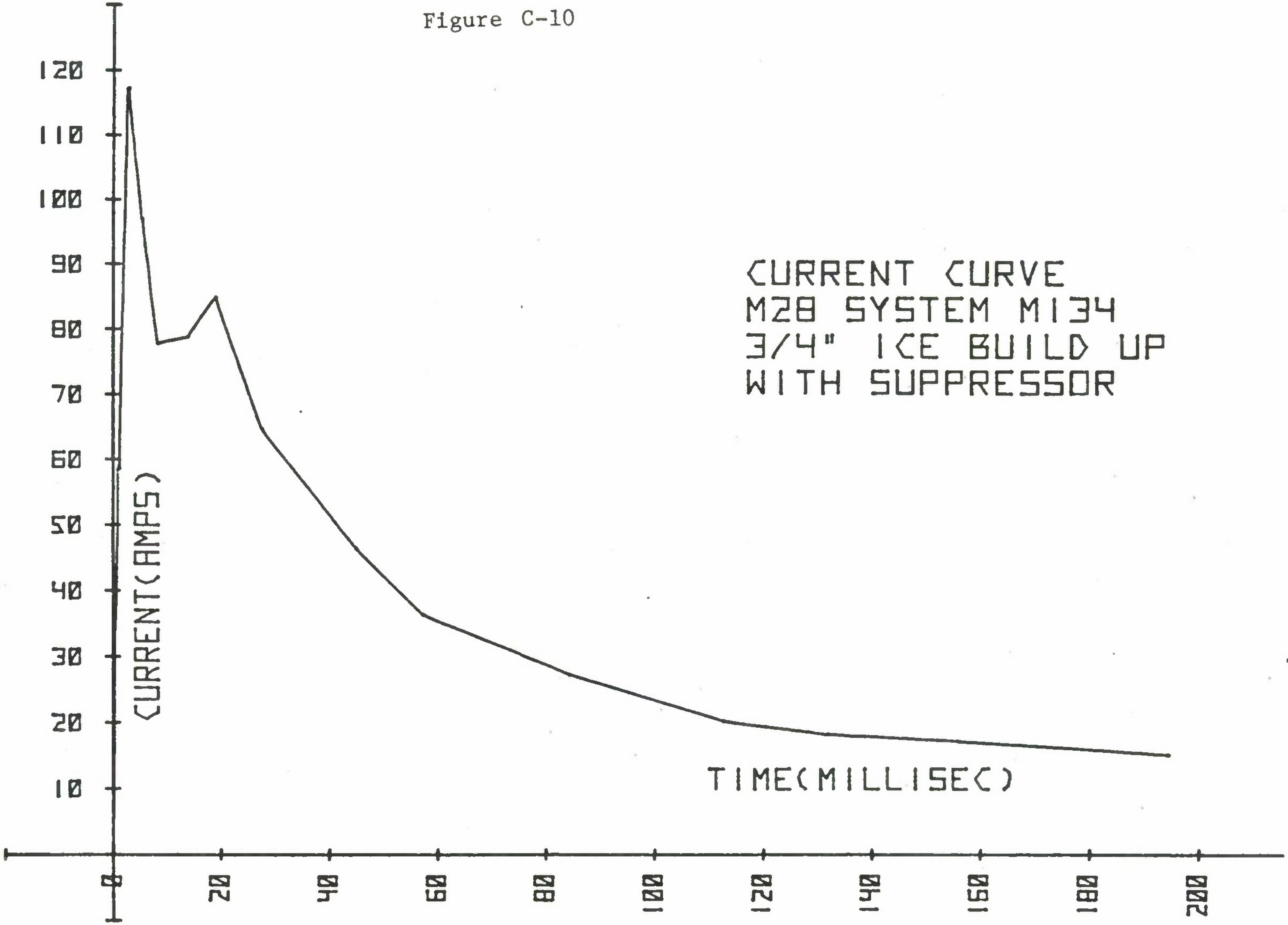

POWER CURVE
M28 SYSTEM M134
3/8" ICE BUILD UP
WITH SUPPRESSOR
POWER(WATTS)
TIME(MILLISEC)
0
20
40
60
80
100
120
140
160
180
200
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

Figure C-9

Figure C-10


CURRENT CURVE
M28 SYSTEM M134
3/4" ICE BUILD UP
WITH SUPPRESSOR
CURRENT(AMPS)
TIME(MILLISEC)
120
110
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200

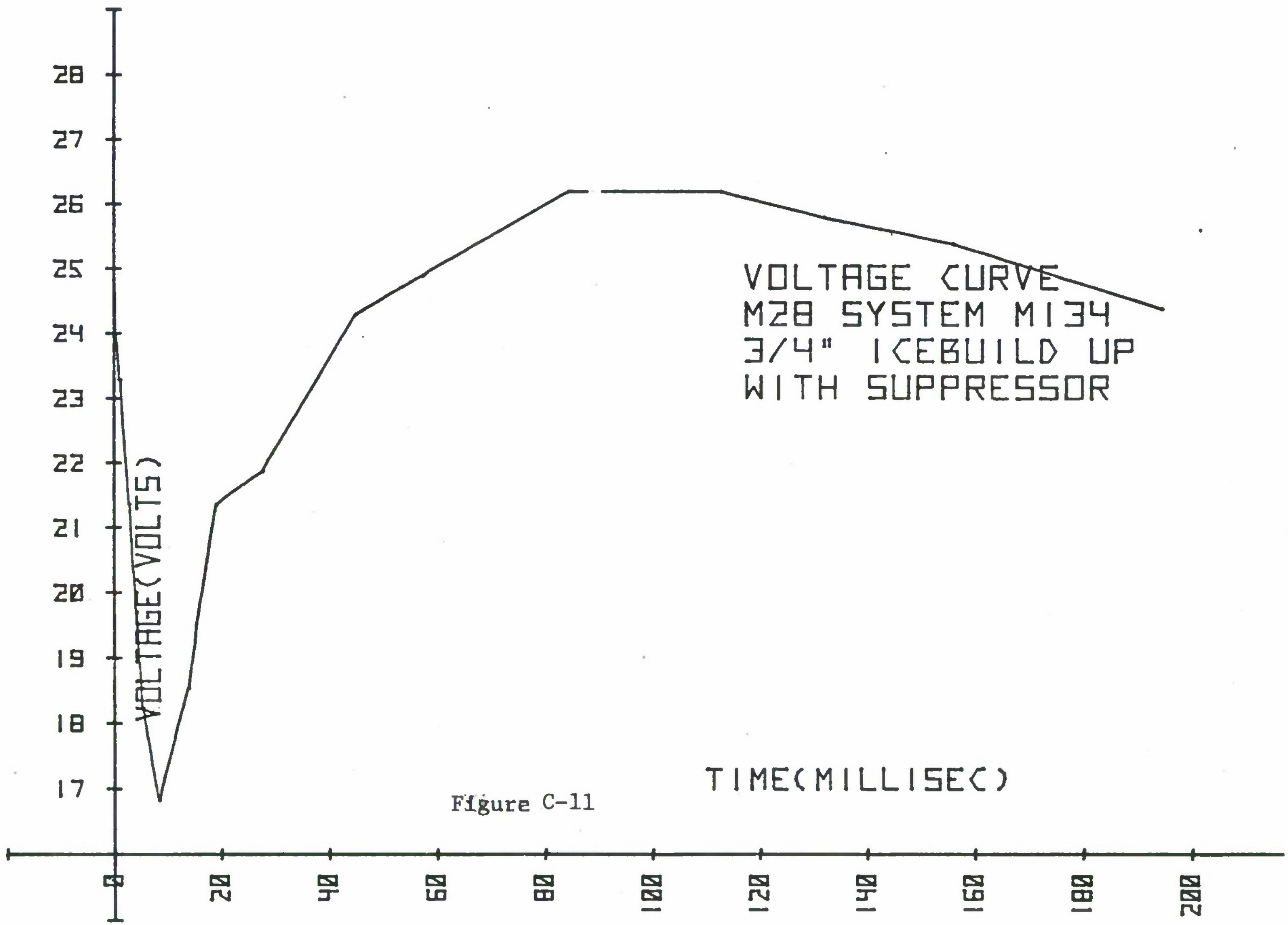
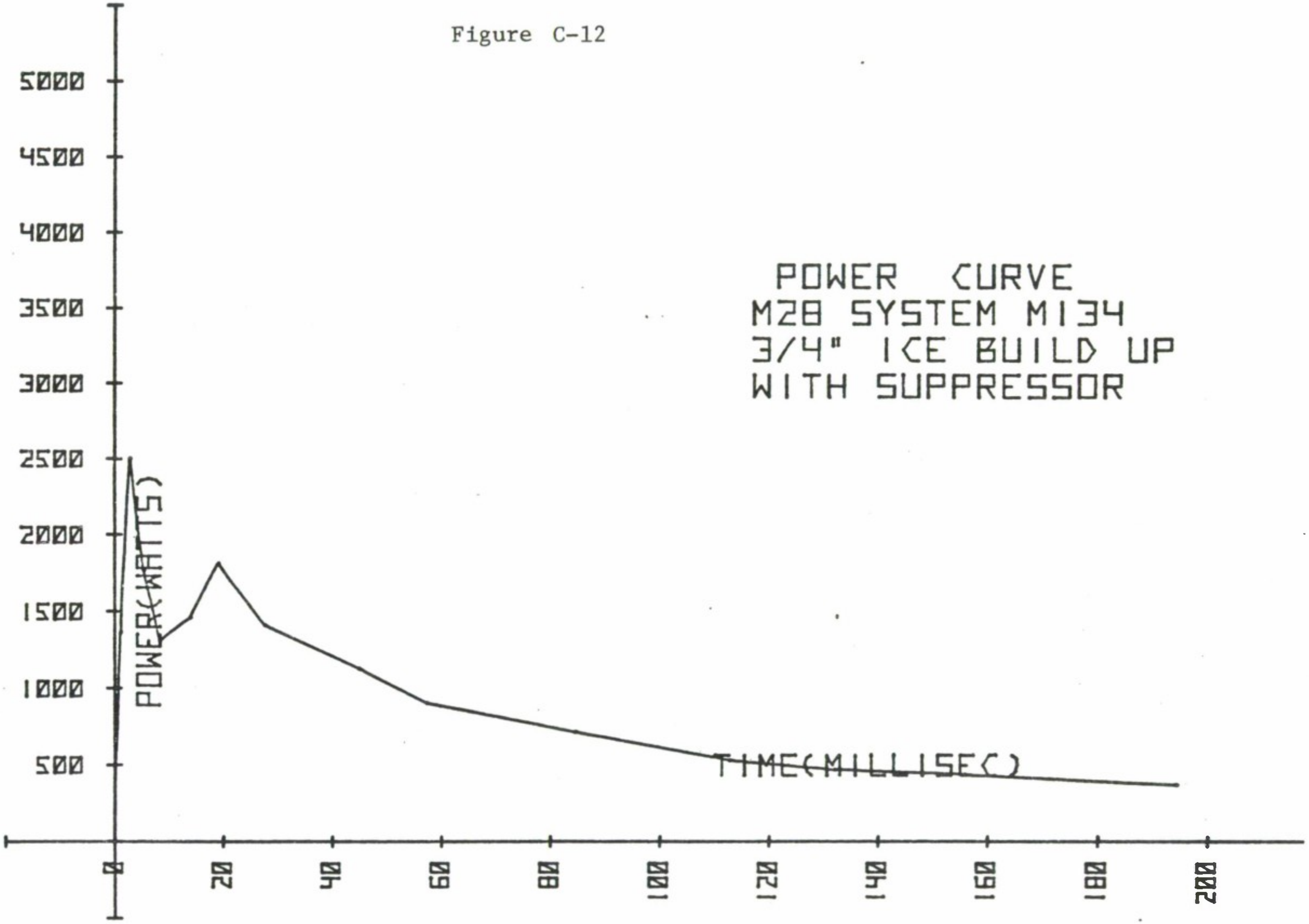

VOLTAGE CURVE
M28 SYSTEM M134
3/4" ICEBUILD UP
WITH SUPPRESSOR
VOLTAGE(VOLTS)
TIME(MILLISEC)
17
18
19
20
21
22
23
24
25
26
27
28
0
20
40
60
80
100
120
140
160
180
200

Figure C-11

Figure C-12


POWER CURVE
M28 SYSTEM M134
3/4" ICE BUILD UP
WITH SUPPRESSOR
POWER(WATTS)
TIME(MILLISEC)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
100
120
140
160
180
200

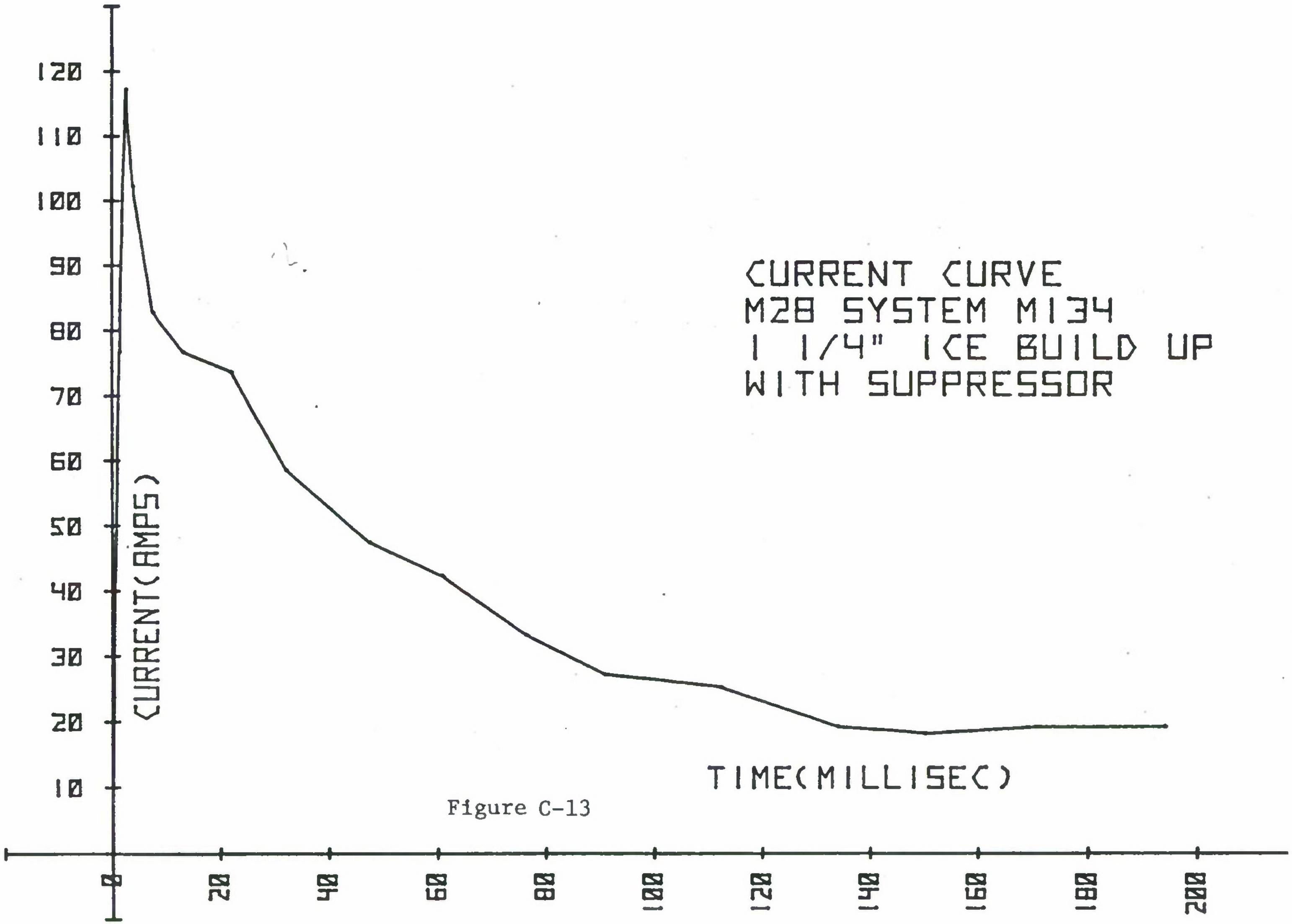
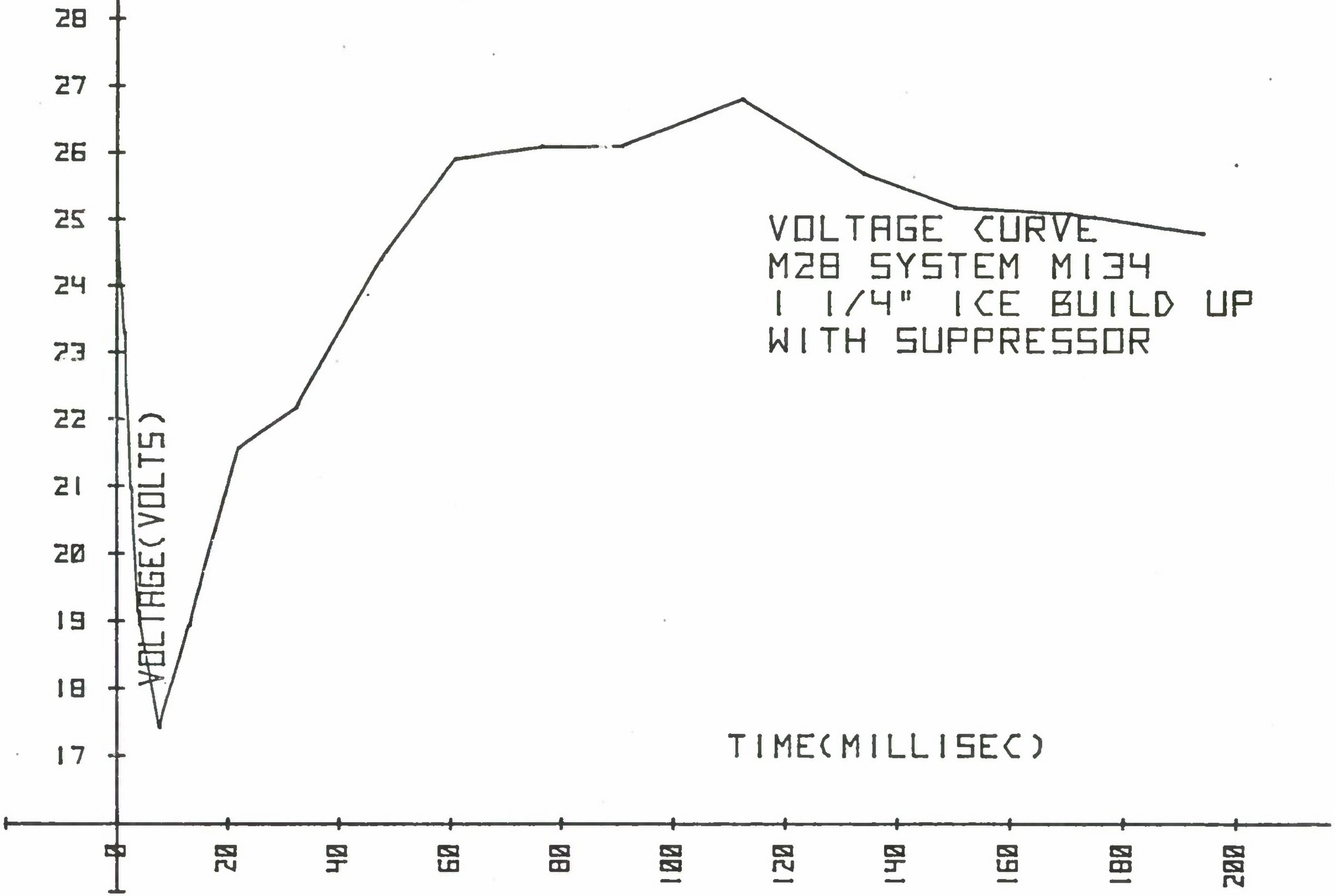

CURRENT CURVE
M28 SYSTEM M134
1 1/4" ICE BUILD UP
WITH SUPPRESSOR
CURRENT(AMPS)
TIME(MILLISEC)
120
110
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200

Figure C-13

Figure C-14



VOLTAGE CURVE
M28 SYSTEM M134
1 1/4" ICE BUILD UP
WITH SUPPRESSOR
VOLTAGE(VOLTS)
TIME(MILLISEC)
28
27
26
25
24
23
22
21
20
19
18
17
0
20
40
60
80
100
120
140
160
180
200

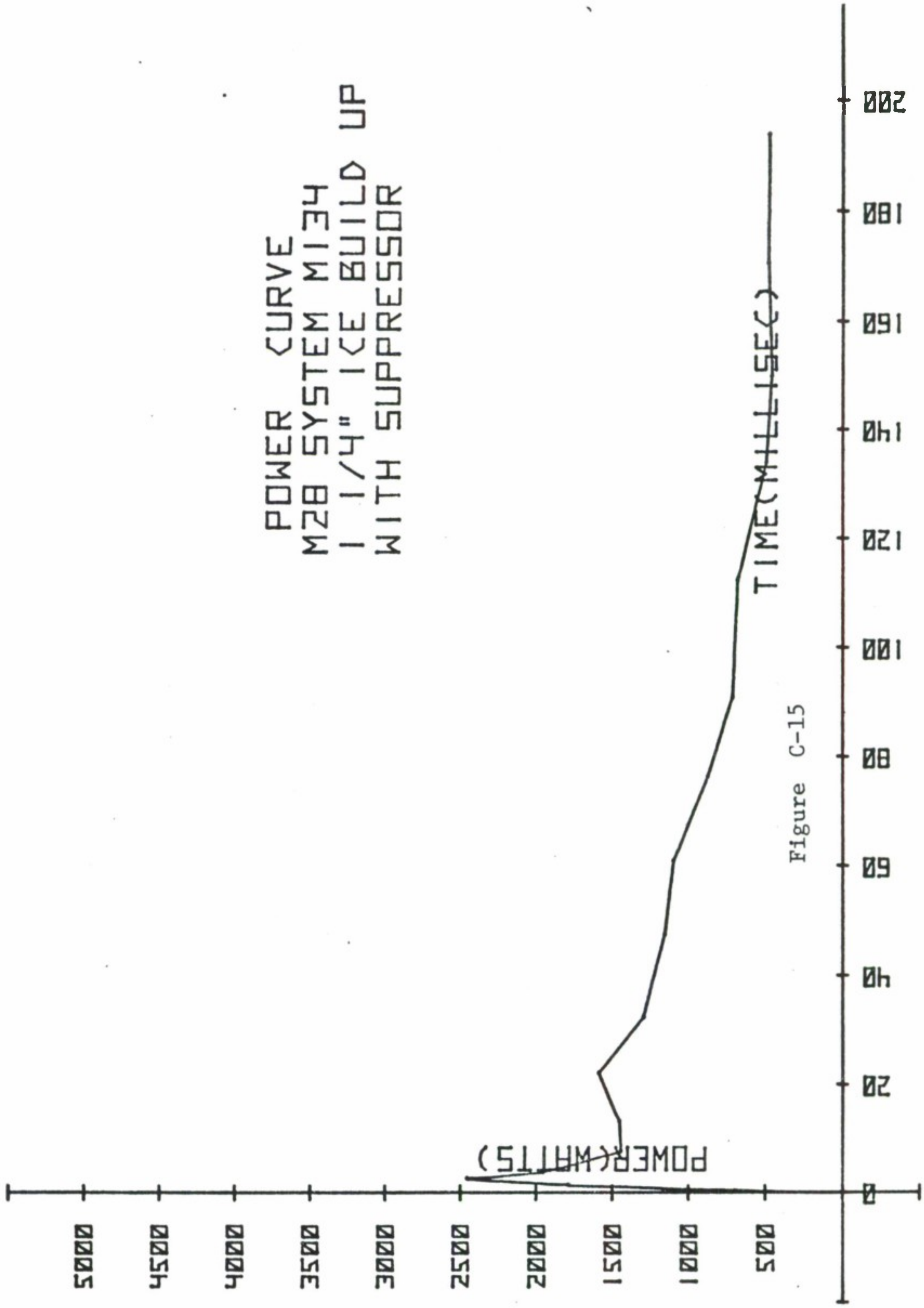

POWER CURVE
M28 SYSTEM M134
1 1/4" ICE BUILD UP
WITH SUPPRESSOR
POWER(WATTS)
TIME(MILLISEC)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
20
40
60
80
100
120
140
160
180
200

Figure C-15

Blank

APPENDIX D

PHASE IV DATA

40mm, 129 Grenade Launcher

TABLE D-1

40mm Grenade Launcher

Rds Fired	Type of Fire	Rate of Fire	Airflow, ft./min.	Ice Accum.	Temp. of Room	Operating Voltage
5	Auto	400 spm	N/A	N/A	Ambient	25V
5	Auto	400 spm	1200	1/16"	0°F	25V
5	Auto	400 spm	1200	1/16"	0°F	25V
4	Auto	400 spm	1200	1/16"	0°F	25V
3	Auto	400 spm	1200	1/16"	0°F	25V
3	Auto	400 spm	1200	3/8"	0°F	25V
3	Auto	400 spm	1200	3/8"	0°F	25V
3	Auto	400 spm	1200	3/4"	0°F	25V
3	Auto	400 spm	1200	1 1/4"	0°F	25V
3	Auto	400 spm	1200	1 1/4"	0°F	25V
3	Auto	400 spm	1200	1 1/4"	0°F	25V

TABLE D-2

40mm Barrel Measurements
(Before Tests)

Distance From Muzzle	Barrels #1 Bore[a]	Barrels #1 External[b]	Barrels #2 Bore[a]	Barrels #2 External[b]
1	1.6072	1.7975	1.6069	1.7990
2	1.6068	1.7975	1.6067	1.7990
3	1.6065	1.7975	1.6065	1.7985
4	1.6065	1.7973	1.6066	1.7985
5	1.6065	1.7975	1.6065	1.7990
6	1.6067	1.7972	1.6065	1.7990
7	1.6068	1.7972	1.6065	1.7990
8	1.6068	1.7975	1.6068	1.7990
9	1.6069	1.7975	1.6066	1.7990
10	1.6070	1.7975	1.6067	1.7990

Notes: a. Drawing dimension for bore is 1.606 dia +.003.

b. Drawing dimension for this area of barrel O.D. is 1.800 dia -.002.

TABLE D-3

40mm Barrel Measurements
(After Firing)

Distance From Muzzle	Barrel #2, O.D. Measurement
2"	1.797
4"	1.797
6"	1.797
8"	1.797

Notes:

a. Dummy rounds were caught without damage.

b. Ice in muzzle did not cause damage to soft nosed dummy cartridges.

c. O.D. measurements are all within tolerance for Barrel #2.

d. Bore measurements on Barrel #1 varied from 1.6062 to 1.6068, all of which are within drawing tolerance.

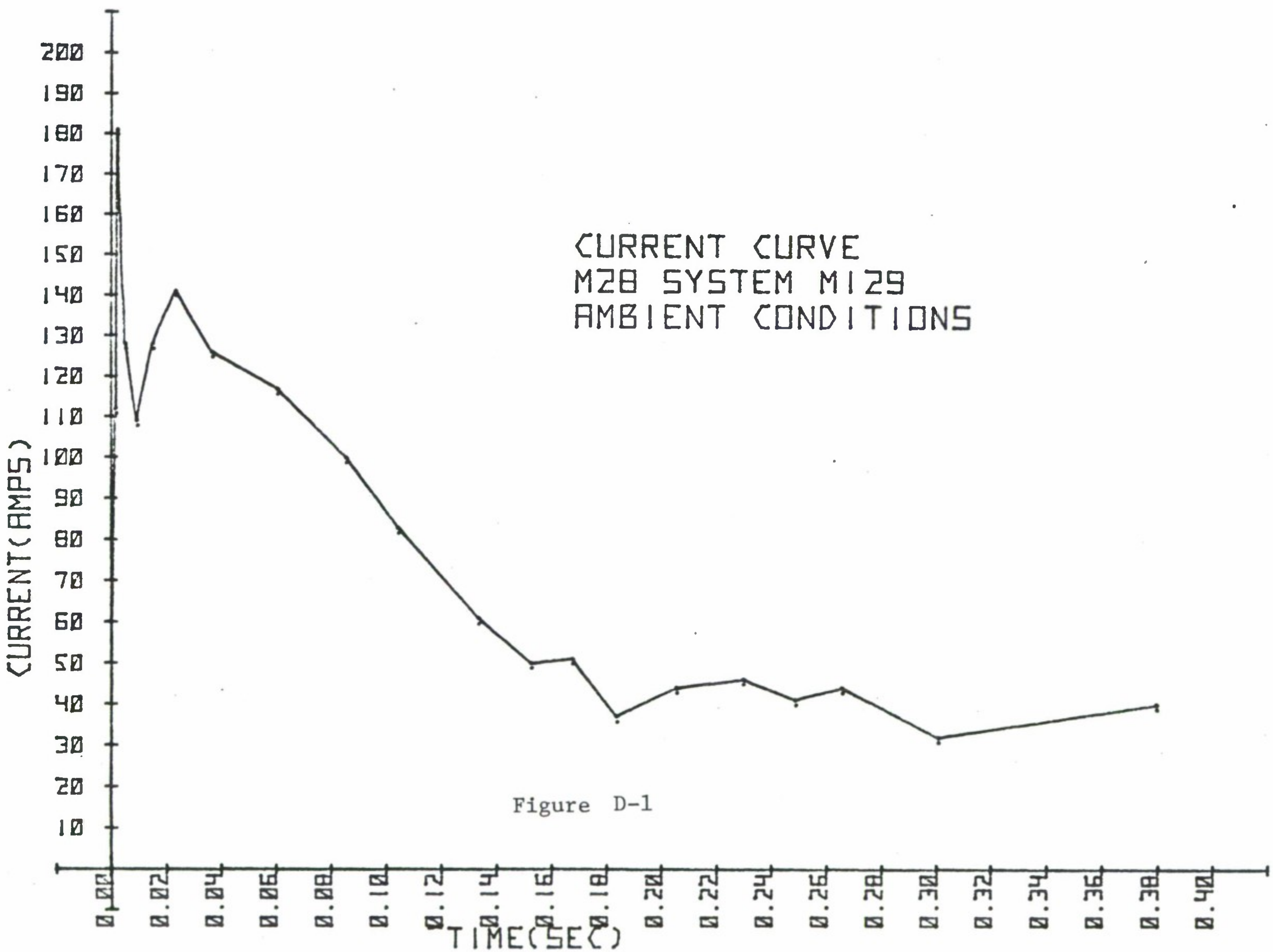
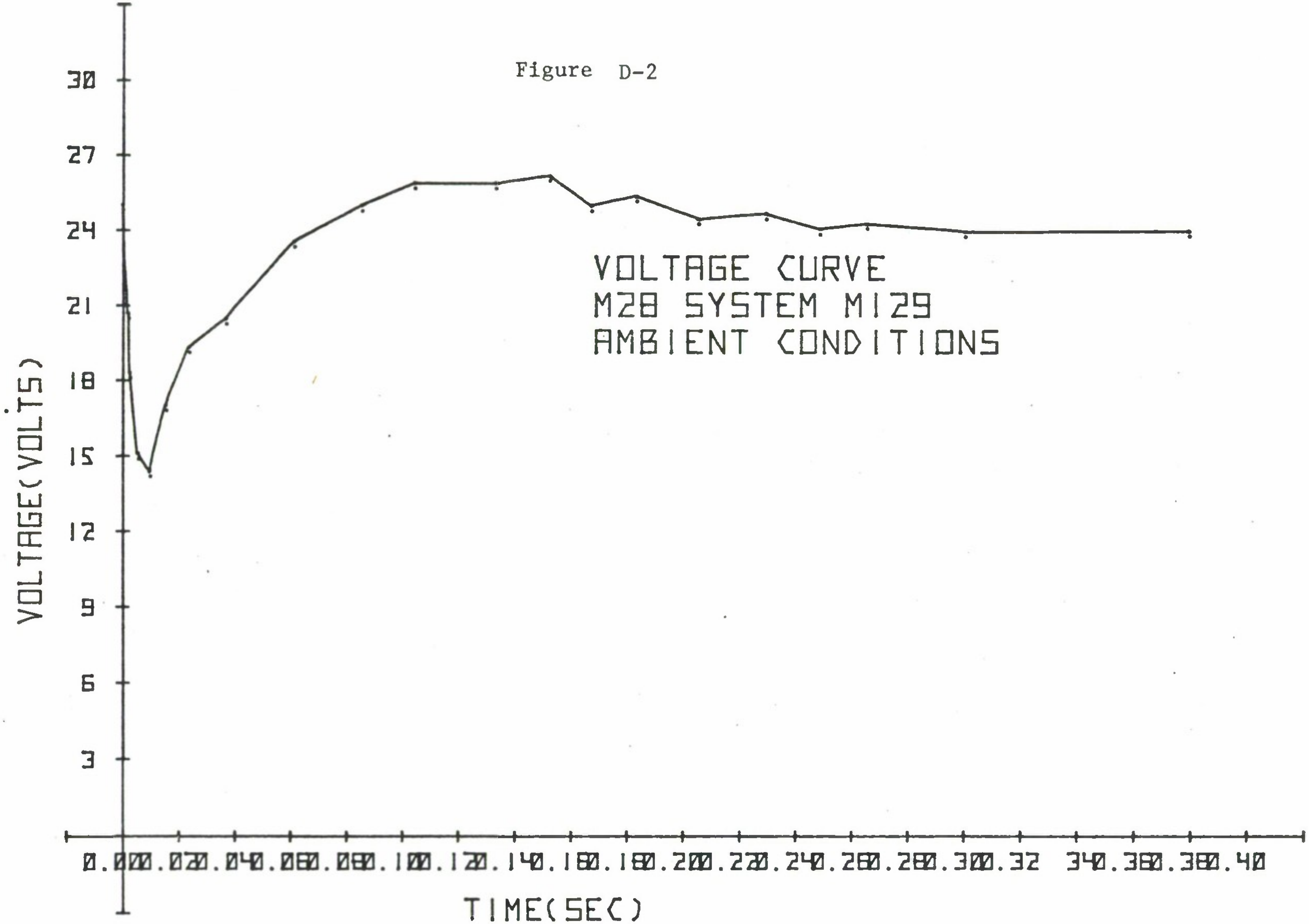

CURRENT CURVE
M28 SYSTEM M129
AMBIENT CONDITIONS
CURRENT(AMPS)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30
0.32
0.34
0.36
0.38
0.40
TIME(SEC)

Figure D-1

Figure D-2


VOLTAGE CURVE
M28 SYSTEM M129
AMBIENT CONDITIONS
VOLTAGE(VOLTS)
30
27
24
21
18
15
12
9
6
3
TIME(SEC)

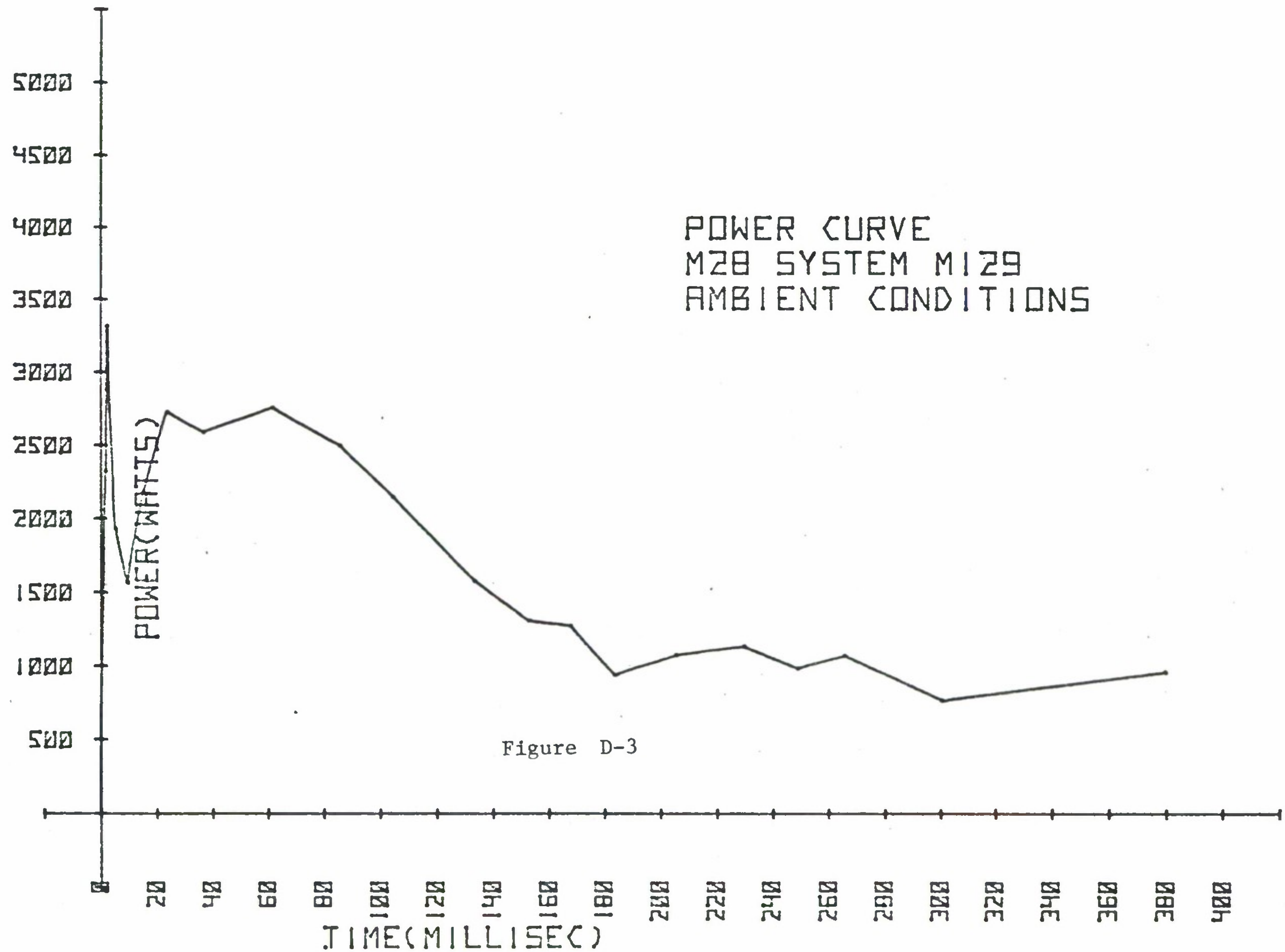
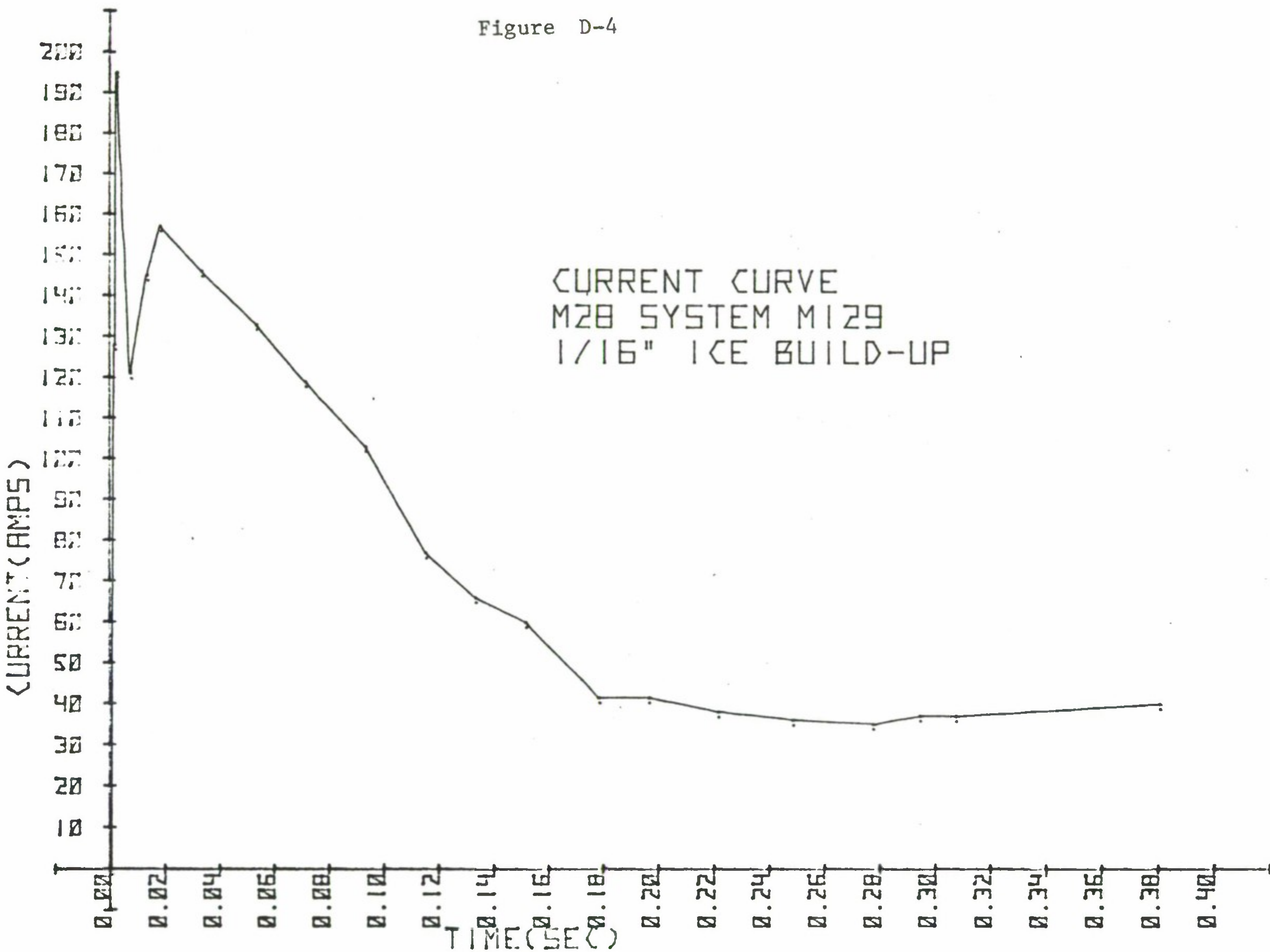

POWER CURVE
M28 SYSTEM M129
AMBIENT CONDITIONS
POWER(WATTS)
TIME(MILLISEC)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400

Figure D-3

Figure D-4


CURRENT CURVE
M28 SYSTEM M129
1/16" ICE BUILD-UP
CURRENT (AMPS)
TIME (SEC)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30
0.32
0.34
0.36
0.38
0.40

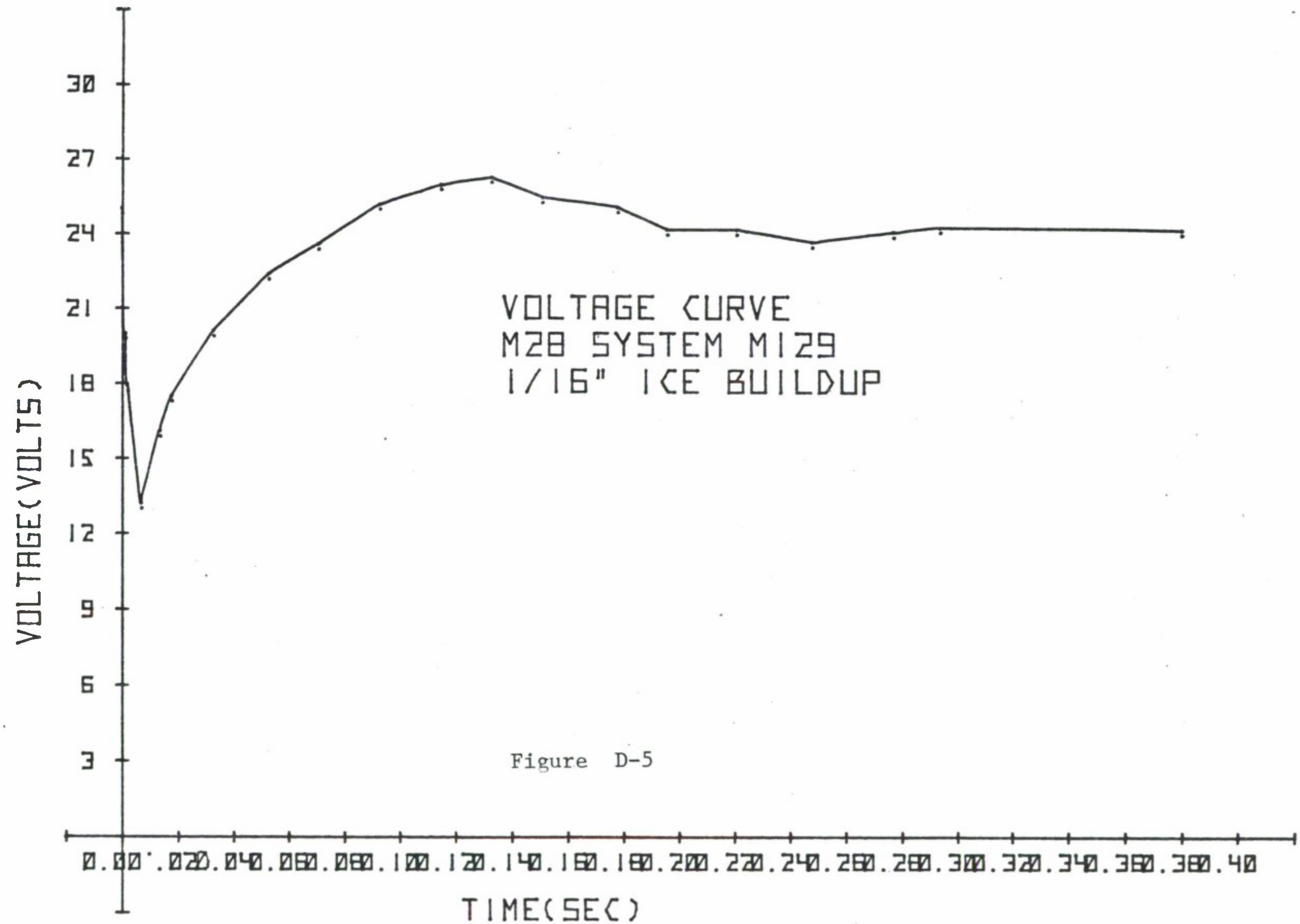
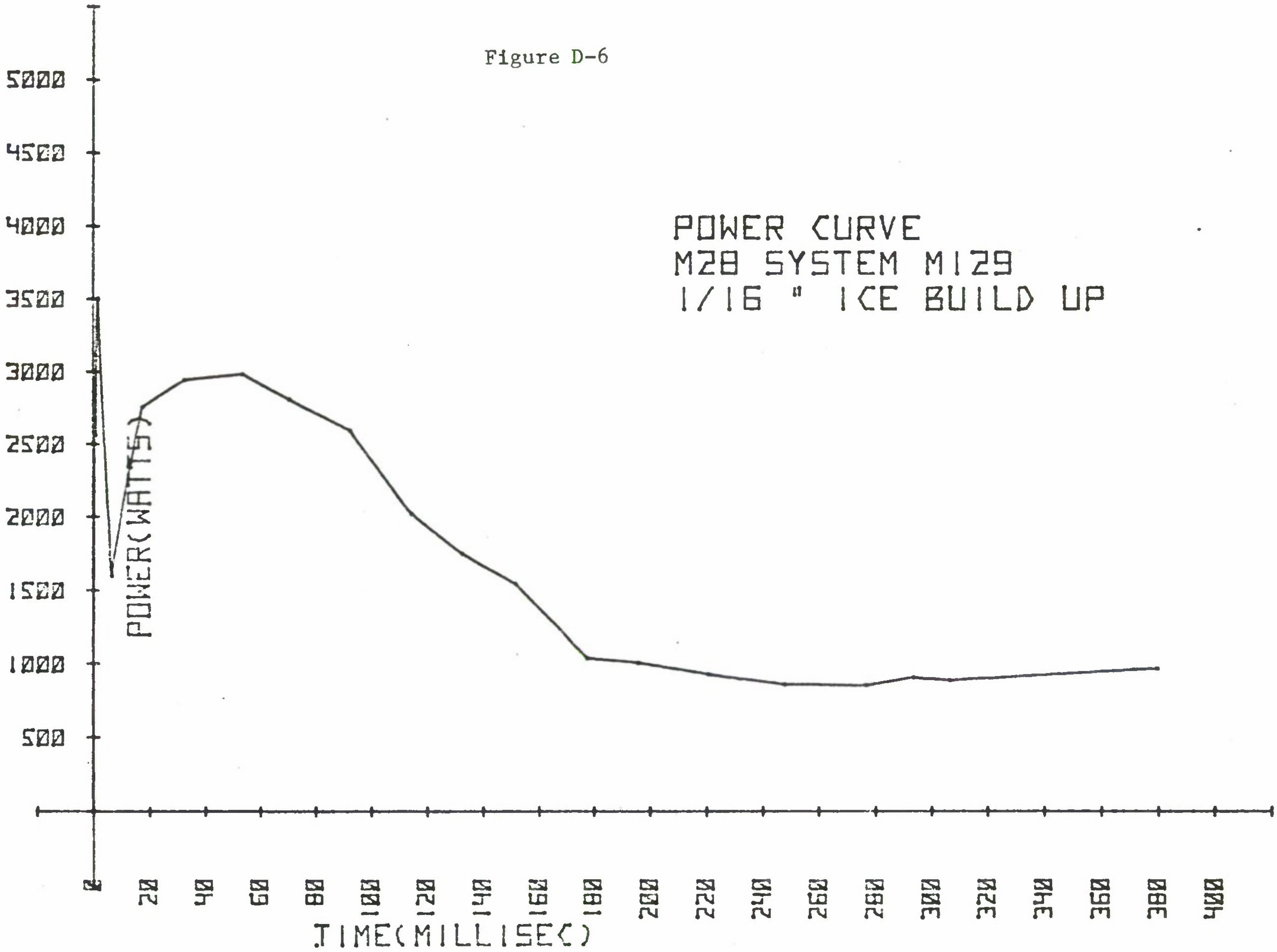

VOLTAGE CURVE
M28 SYSTEM M129
1/16" ICE BUILDUP
VOLTAGE(VOLTS)
30
27
24
21
18
15
12
9
6
3
TIME(SEC)

Figure D-5

Figure D-6


POWER CURVE
M28 SYSTEM M129
1/16 " ICE BUILD UP
POWER(WATTS)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
TIME(MILLISEC)

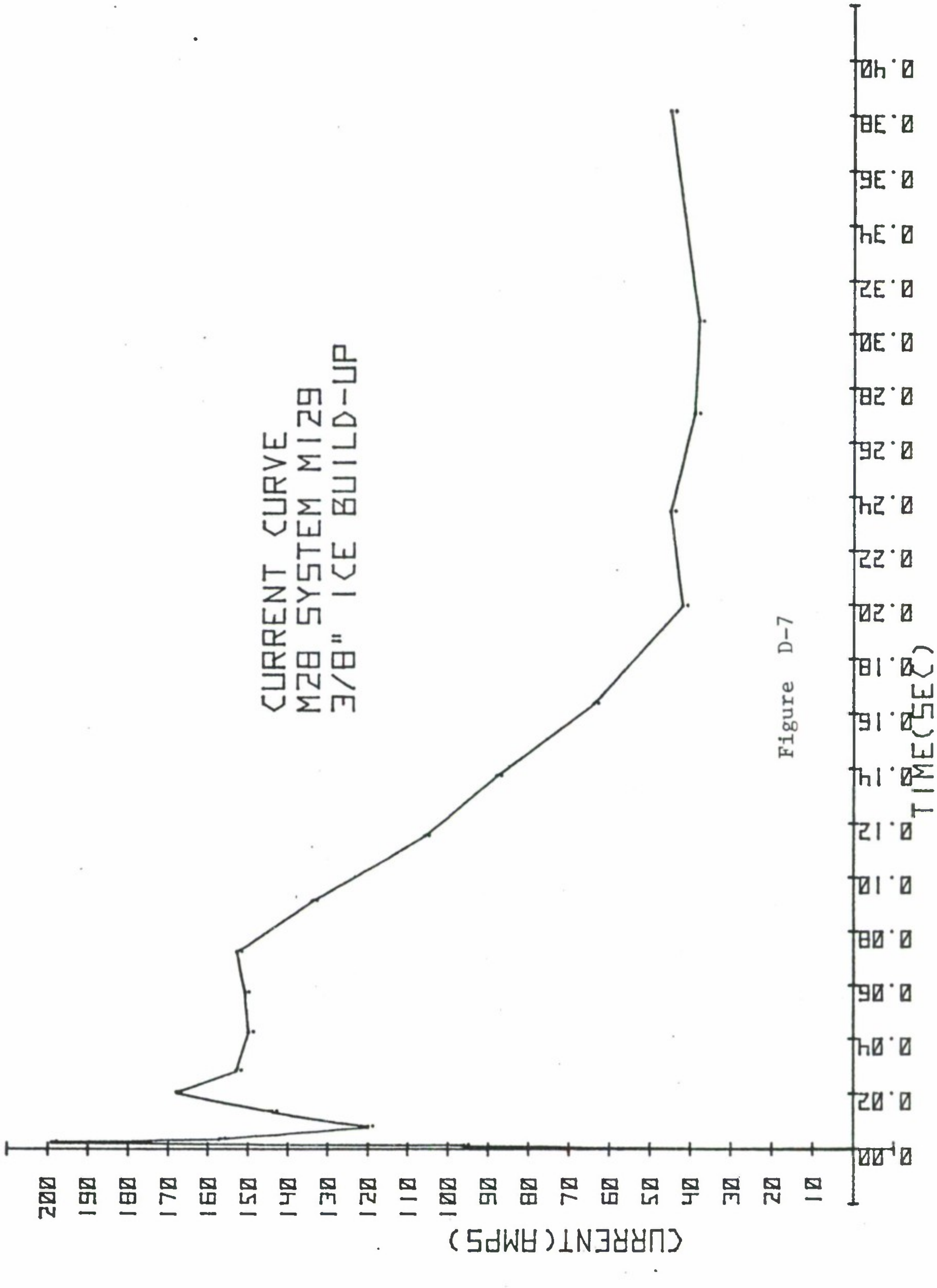
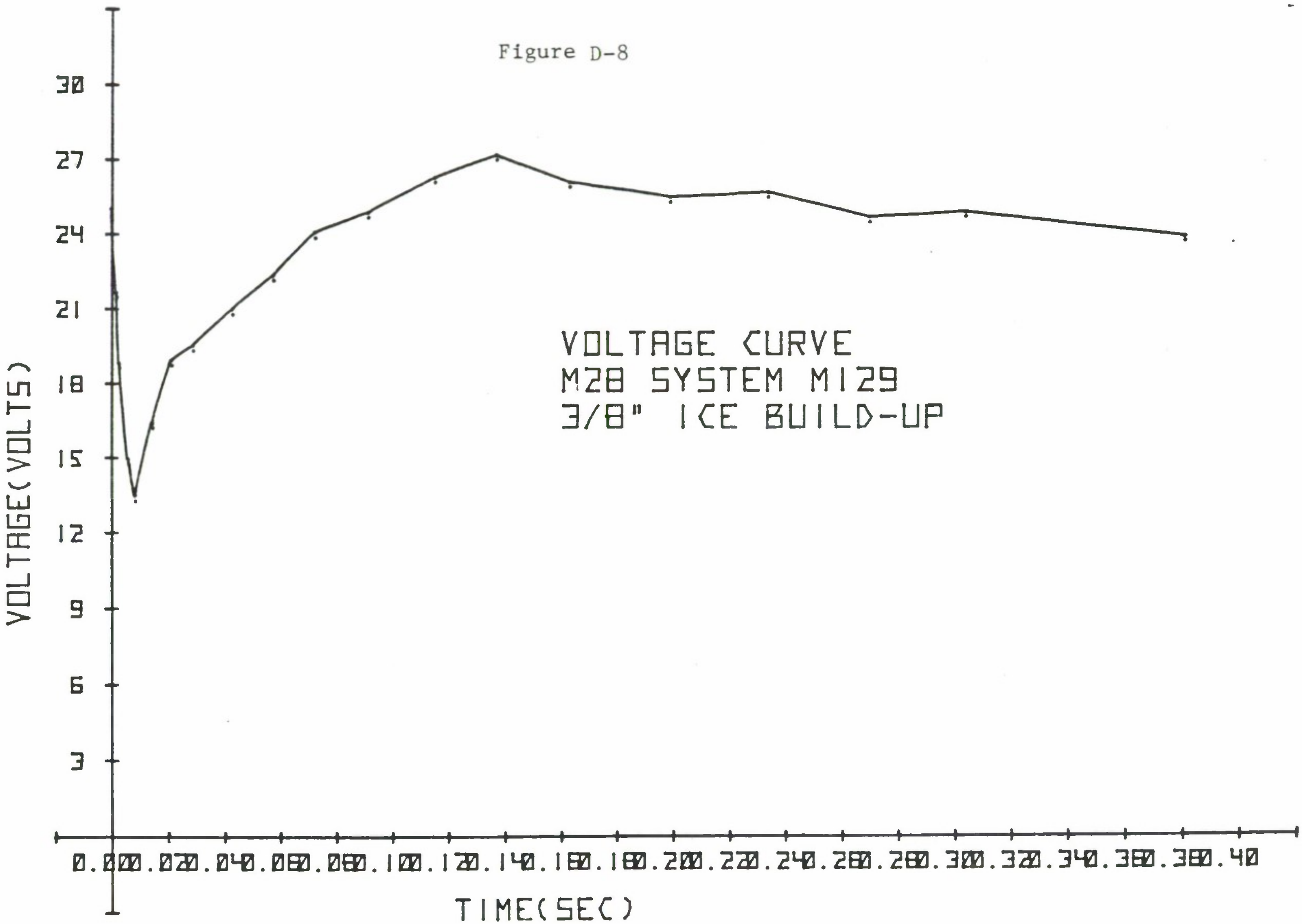

CURRENT CURVE
M28 SYSTEM M129
3/8" ICE BUILD-UP
CURRENT(AMPS)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
TIME(SEC)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30
0.32
0.34
0.36
0.38
0.40

Figure D-7

Figure D-8


VOLTAGE CURVE
M28 SYSTEM M129
3/8" ICE BUILD-UP
VOLTAGE(VOLTS)
30
27
24
21
18
15
12
9
6
3
TIME(SEC)

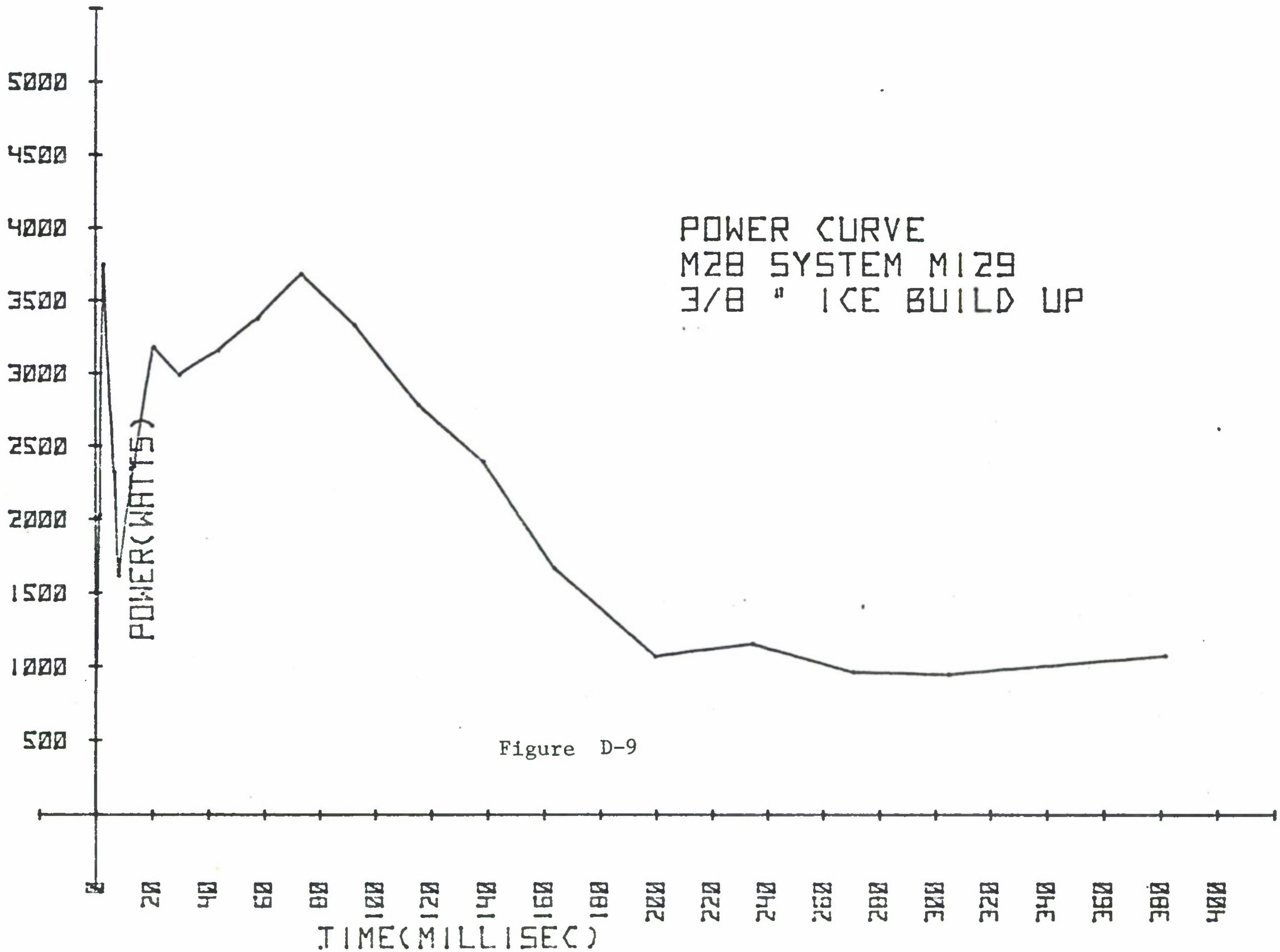

POWER CURVE
M28 SYSTEM M129
3/8 " ICE BUILD UP
POWER(WATTS)
TIME(MILLISEC)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400

Figure D-9

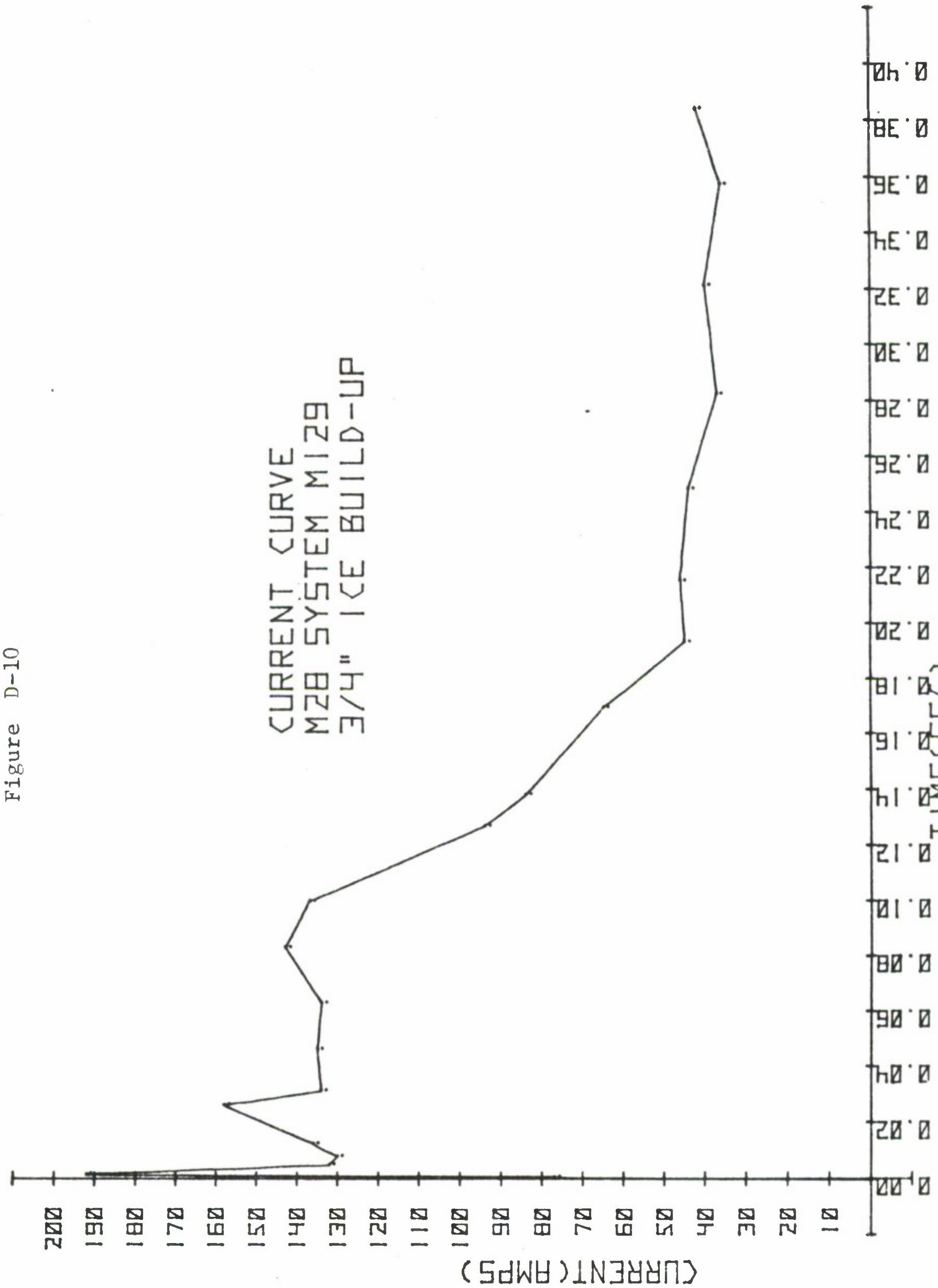

CURRENT CURVE
M28 SYSTEM M129
3/4" ICE BUILD-UP
TIME(SEC)
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36 0.38 0.40
CURRENT(AMPS)
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

Figure D-10

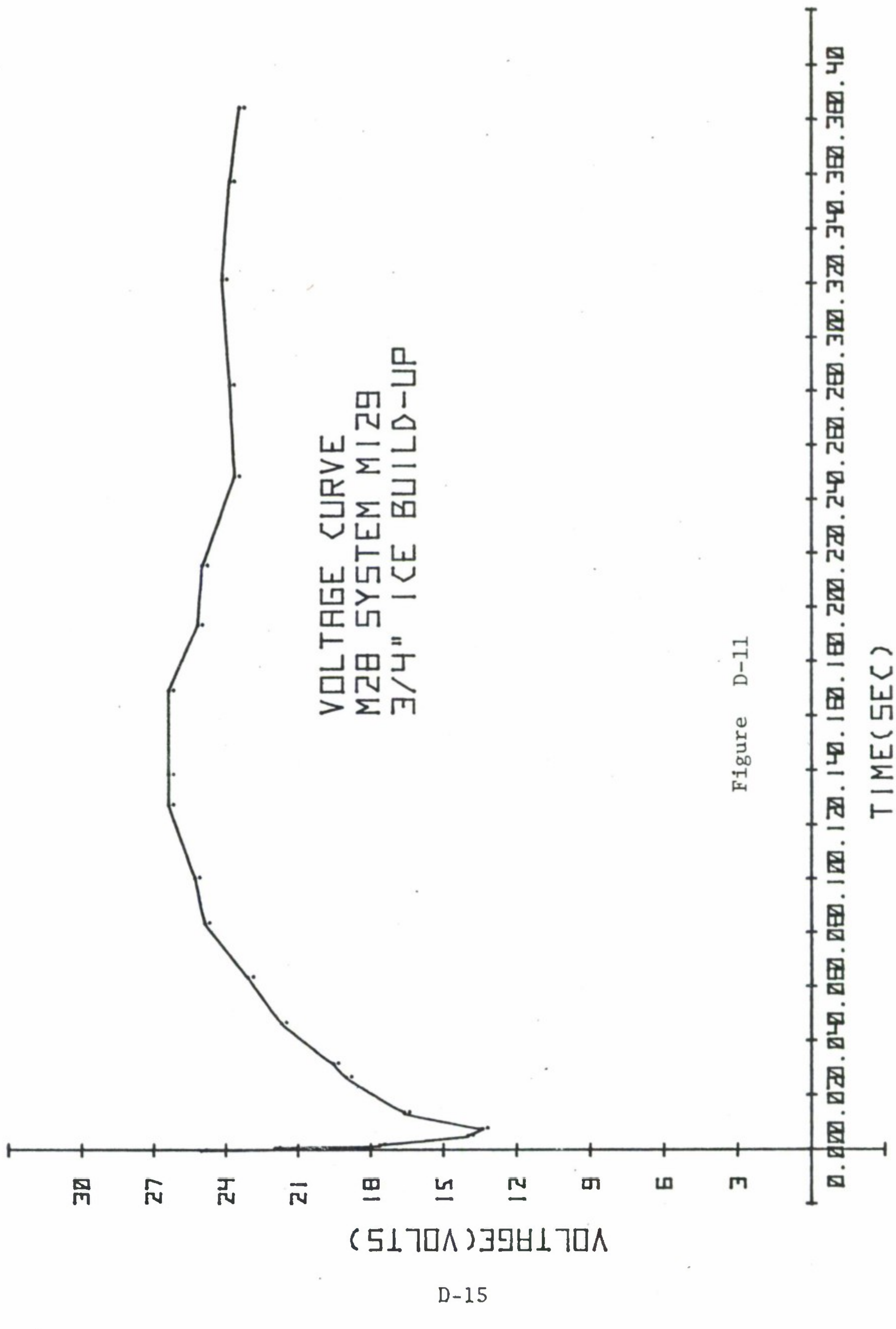
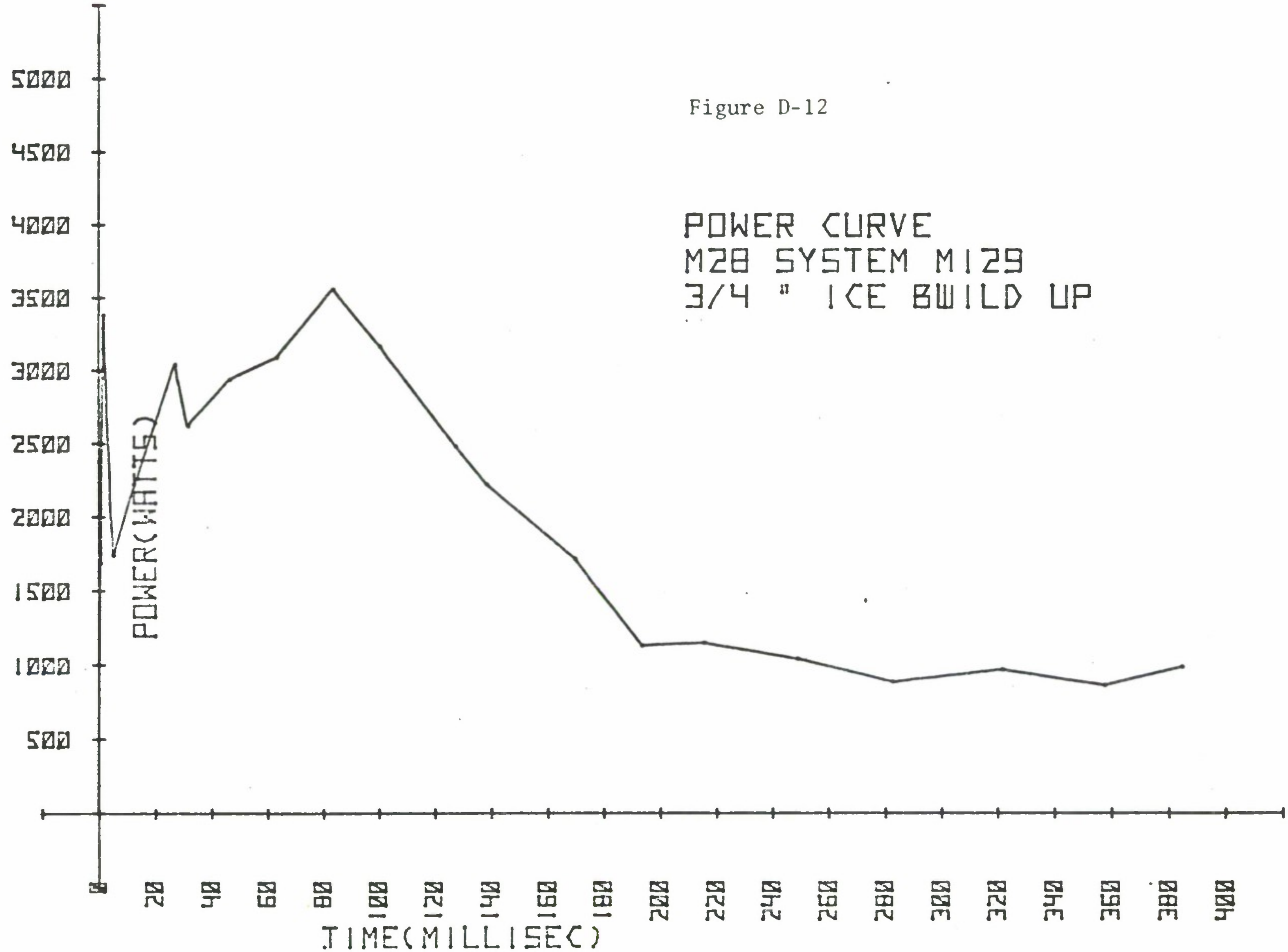

VOLTAGE CURVE
M28 SYSTEM M129
3/4" ICE BUILD-UP
VOLTAGE(VOLTS)
30
27
24
21
18
15
12
9
6
3
TIME(SEC)
0.000.020.040.060.080.100.120.140.160.180.200.220.240.260.280.300.320.340.360.380.40

Figure D-11

Figure D-12


POWER CURVE
M28 SYSTEM M129
3/4 " ICE BWILD UP
POWER(WATTS)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
TIME(MILLISEC)

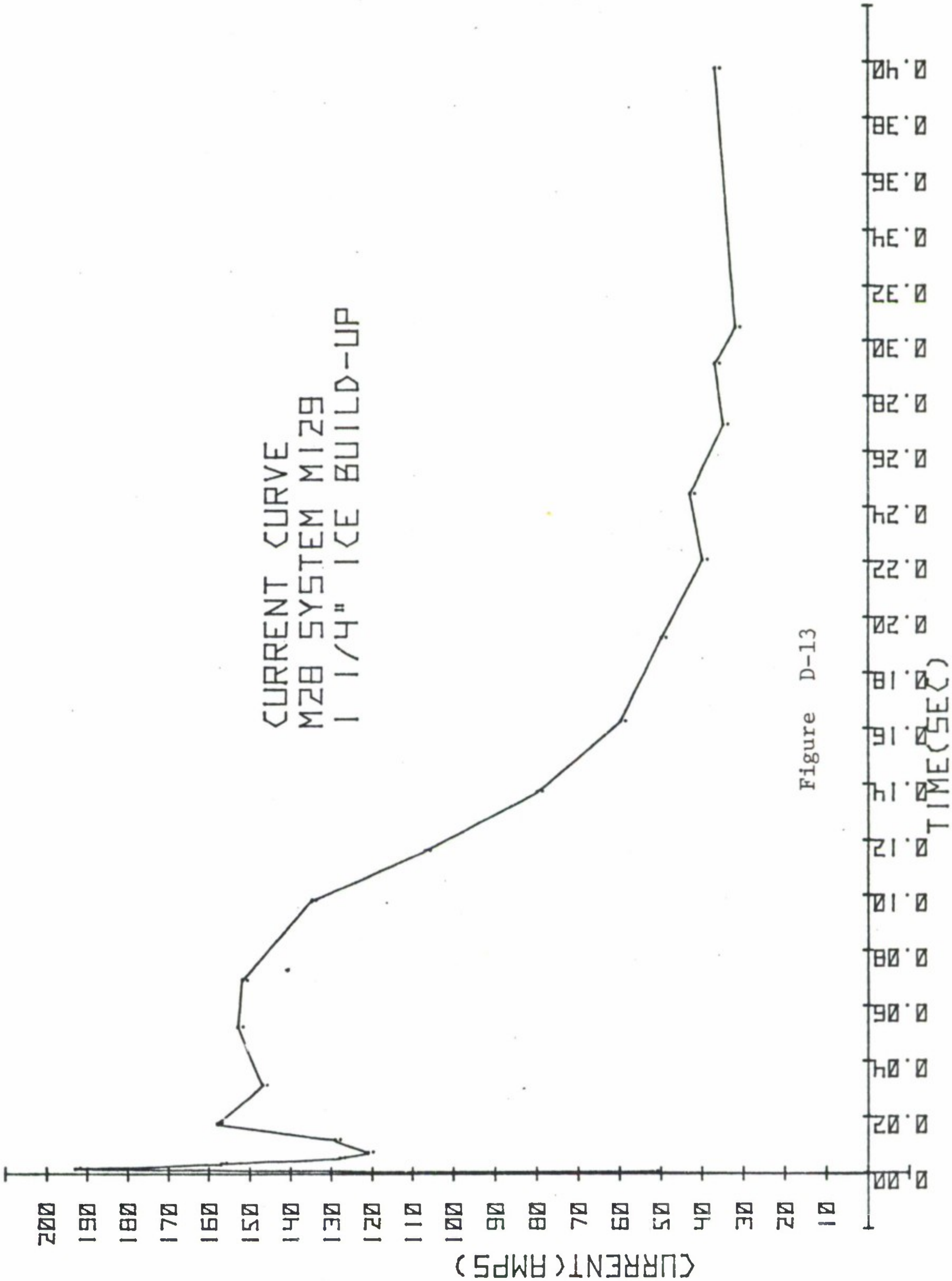
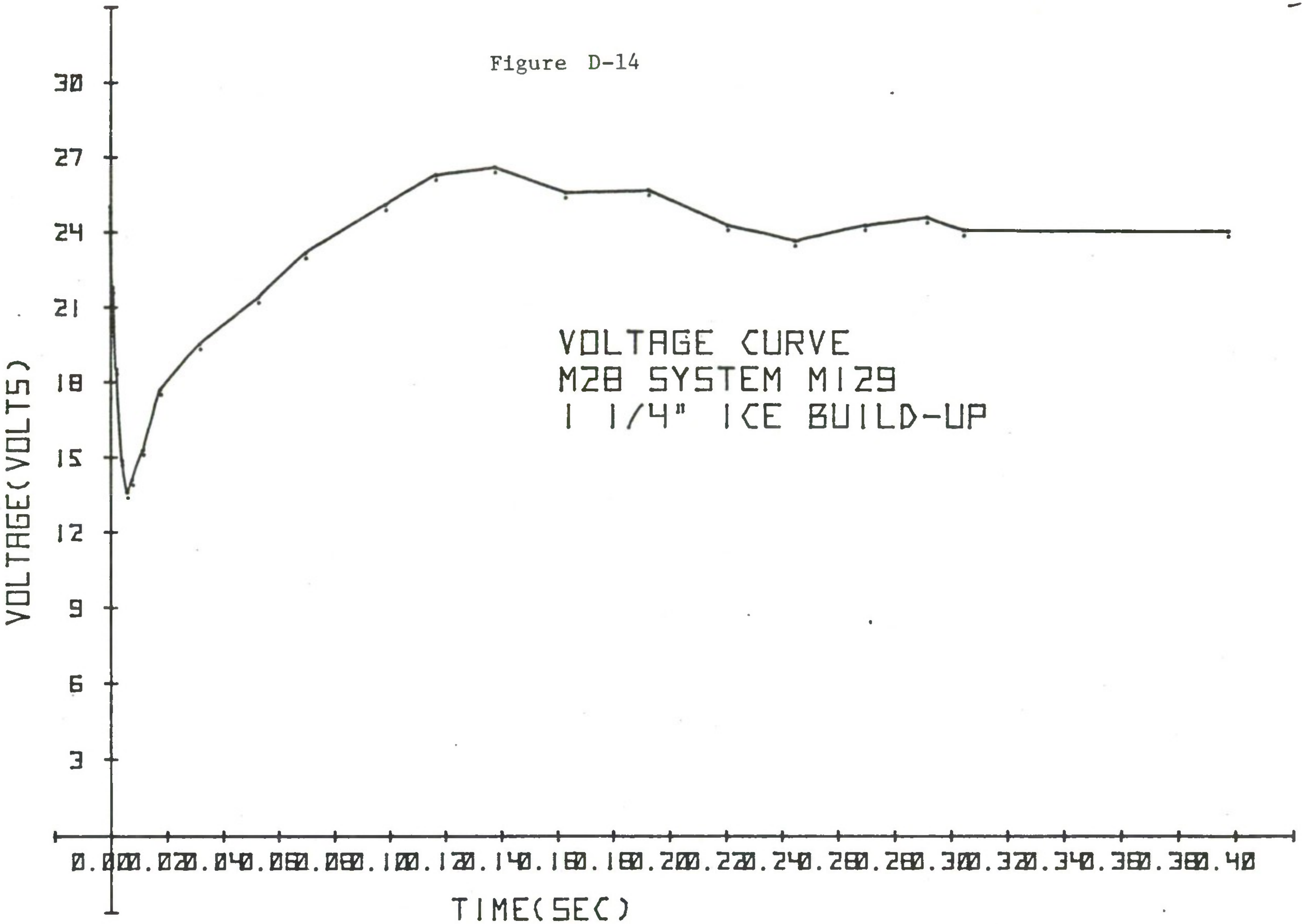

CURRENT CURVE
M28 SYSTEM M129
1 1/4" ICE BUILD-UP
TIME(SEC)
CURRENT(AMPS)
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36 0.38 0.40
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

Figure D-13

Figure D-14


VOLTAGE CURVE
M28 SYSTEM M129
1 1/4" ICE BUILD-UP
VOLTAGE(VOLTS)
30
27
24
21
18
15
12
9
6
3
TIME(SEC)

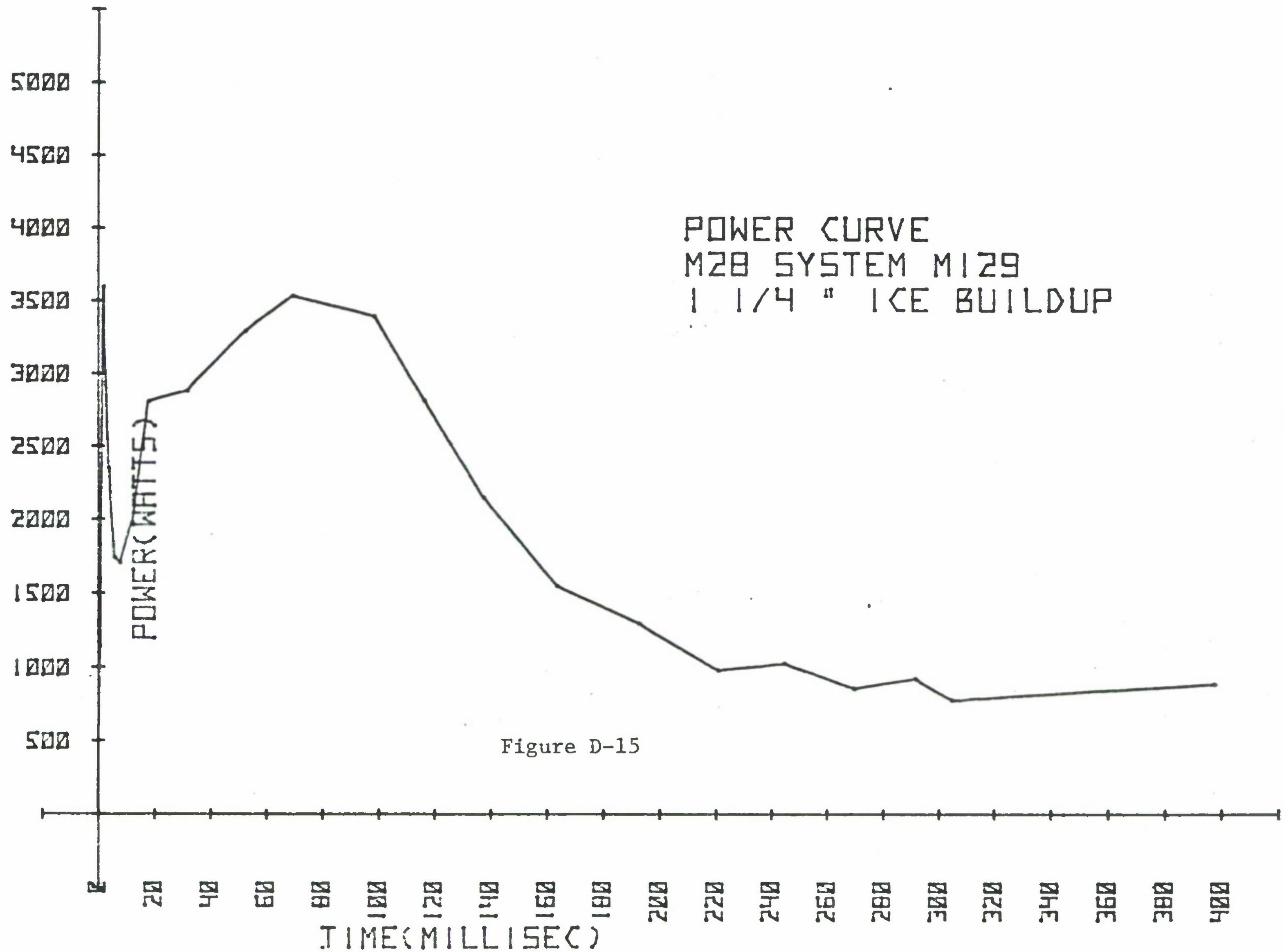

POWER CURVE
M28 SYSTEM M129
1 1/4 " ICE BUILDUP
POWER(WATTS)
TIME(MILLISEC)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400

Figure D-15

Blank

APPENDIX E

PHASE V DATA

Turret Functioning

TABLE E-1

Turret Functioning

Ambient Temperature:

Trials	Time to Depress 75°	Velocity, Degree/sec.	Time to Turn 180° in Azimuth	Velocity, Degree/sec.
1	.740 sec.	101.35	L 2.177 sec.	82.68
2	.743 sec.	100.94	R 2.065 sec.	87.16
3	.743 sec.	100.94	R 2.085 sec.	86.33
4	.685 sec.	109.48	L 2.157 sec.	83.44
5	.755 sec.	99.33	R 2.089 sec.	86.16
6	.724 sec.	103.59	L 2.165 sec.	83.14
7	.705 sec.	106.38	R 2.097 sec.	85.83
8	.699 sec.	107.29	L 2.127 sec.	84.62
9	.749 sec.	100.13	R 2.079 sec.	85.83
10	.708 sec.	105.93	L 2.196 sec.	81.96

TABLE E-1 (Cont.)

Turret Functioning

Trials	Time to Depress 75°	Velocity, Degree/sec.	Time to Turn 180° in Azimuth	Velocity, Degree/sec.
0°F Without Ice:				
1	.883 sec.	84.93	R 3.018 sec.	59.64
2	.857 sec.	87.51	L 2.945 sec.	61.12
3	.860 sec.	87.21	R 2.895 sec.	62.11
4	.843 sec.	88.96	L 2.866 sec.	62.80
5	.834 sec.	89.92	R 2.850 sec.	63.15
6	.825 sec.	89.82	L 2.834 sec.	63.51
0°F With 3/8 Inch Ice:				
1	No Reading	No Reading	No Reading	No Reading
0°F With 3/4 Inch Ice:				
1	No Reading	No Reading	No Reading	No Reading
0°F With 3/4 Inch Ice:				
1	No Reading	No Reading	No Reading	No Reading

TABLE E-1 (Cont.)

Turret Functioning

0°F With 1 1/4 Inch Ice:

Trials	Time to Depress 75°	Velocity, Degree/sec.	Time to Turn 180° in Azimuth	Velocity, Degree/sec.
1	No Reading	No Reading	No Reading	No Reading

Notes: a. No tests were conducted at 1/16 inch ice thickness to expedite the test program.

b. No velocity readings were obtained for any of the icing tests due mainly to the instrumentation and turret control box.

APPENDIX F

PHASE VI DATA

20mm, M195 Gun

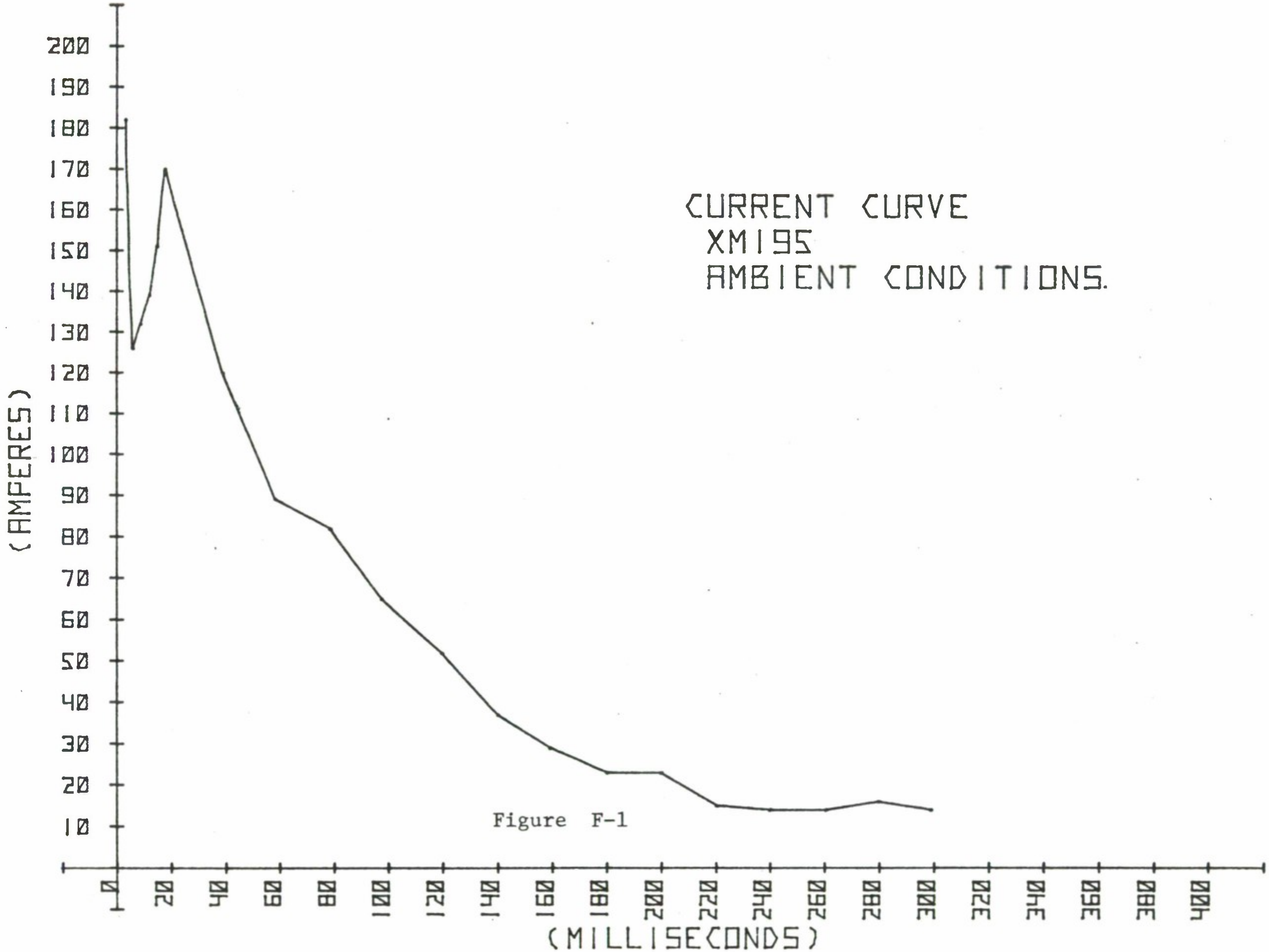
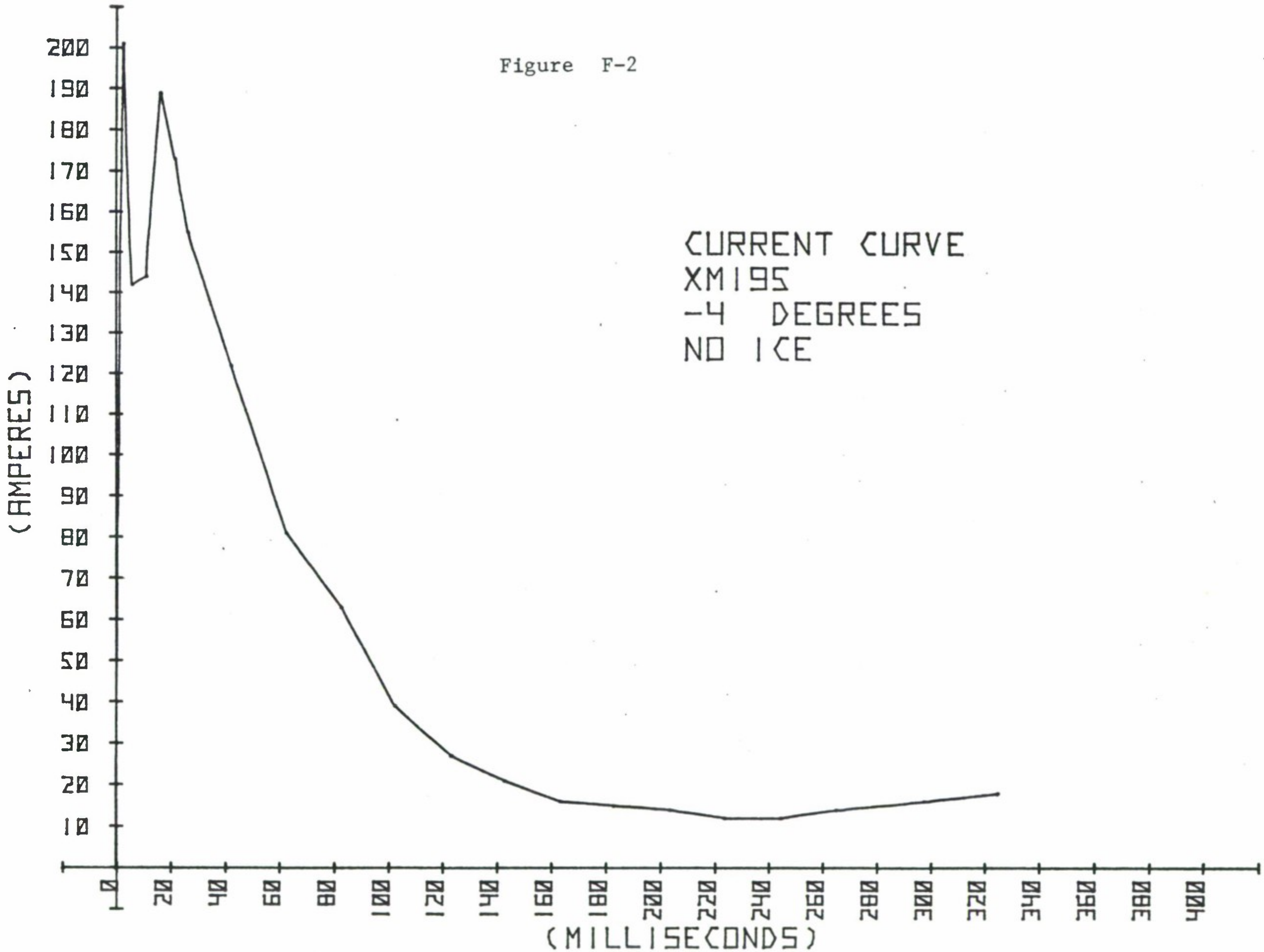

CURRENT CURVE
XM195
AMBIENT CONDITIONS.
(AMPERES)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

Figure F-1

Figure F-2



CURRENT CURVE
XM195
-4 DEGREES
NO ICE
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(AMPERES)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

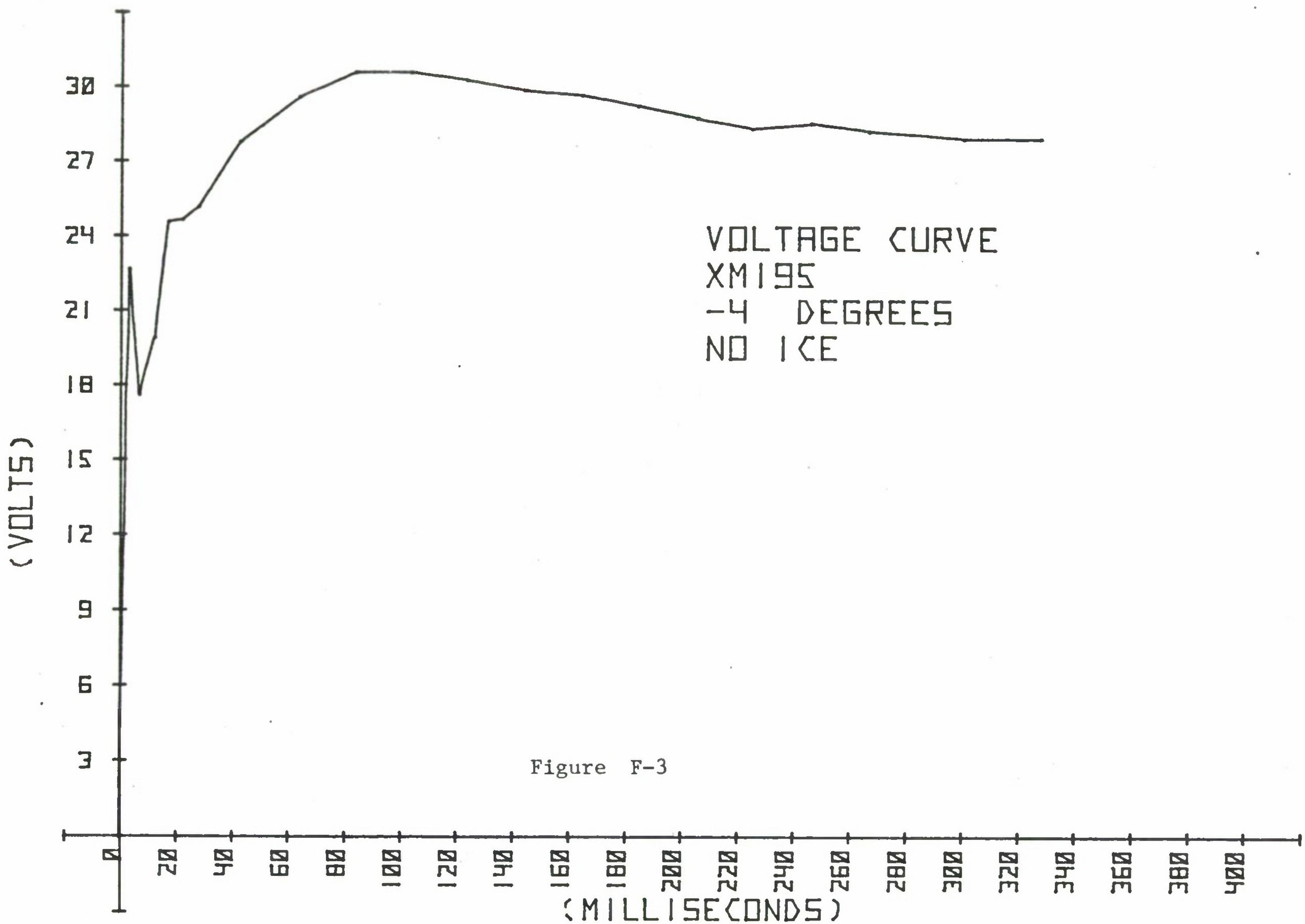
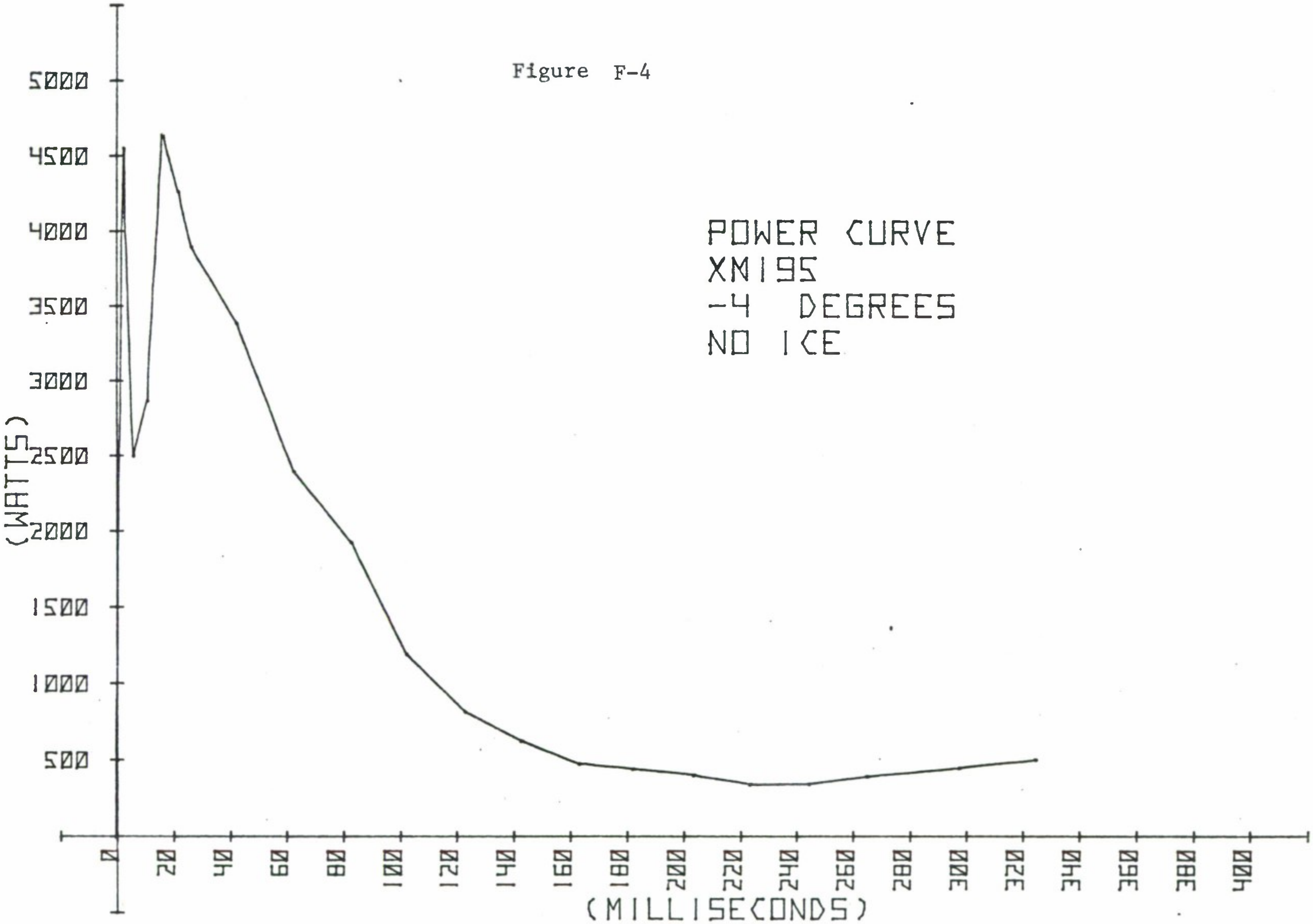

VOLTAGE CURVE
XM195
-4 DEGREES
NO ICE
30
27
24
21
18
15
12
9
6
3
(VOLTS)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

Figure F-3

Figure F-4


POWER CURVE
XM195
-4 DEGREES
NO ICE
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
(WATTS)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

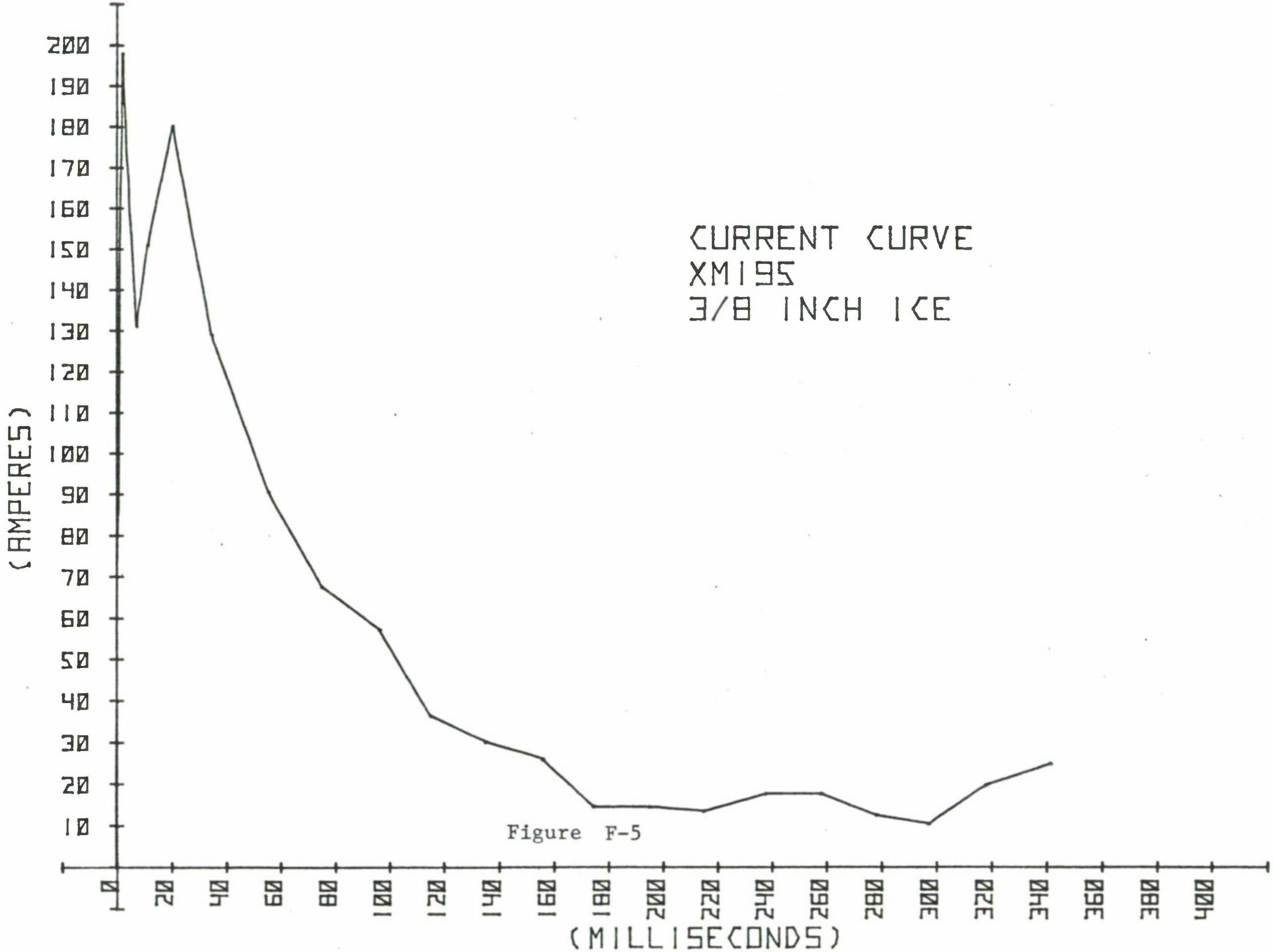

CURRENT CURVE
XM195
3/8 INCH ICE
(AMPERES)
(MILLISECONDS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
220
240
260
280
300
320
340
360
380
400

Figure F-5

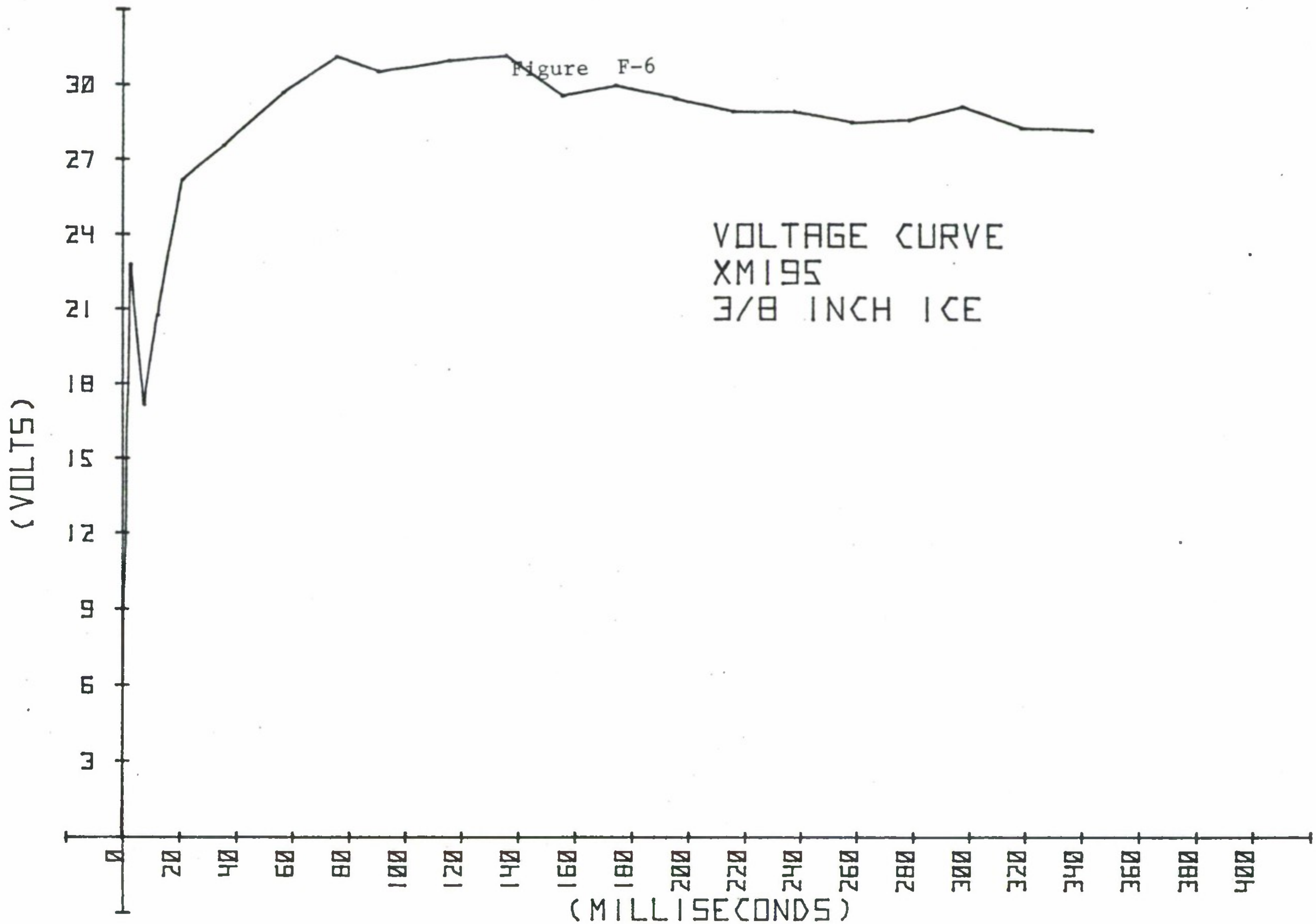

VOLTAGE CURVE
XM195
3/8 INCH ICE
(VOLTS)
30
27
24
21
18
15
12
9
6
3
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

Figure F-6

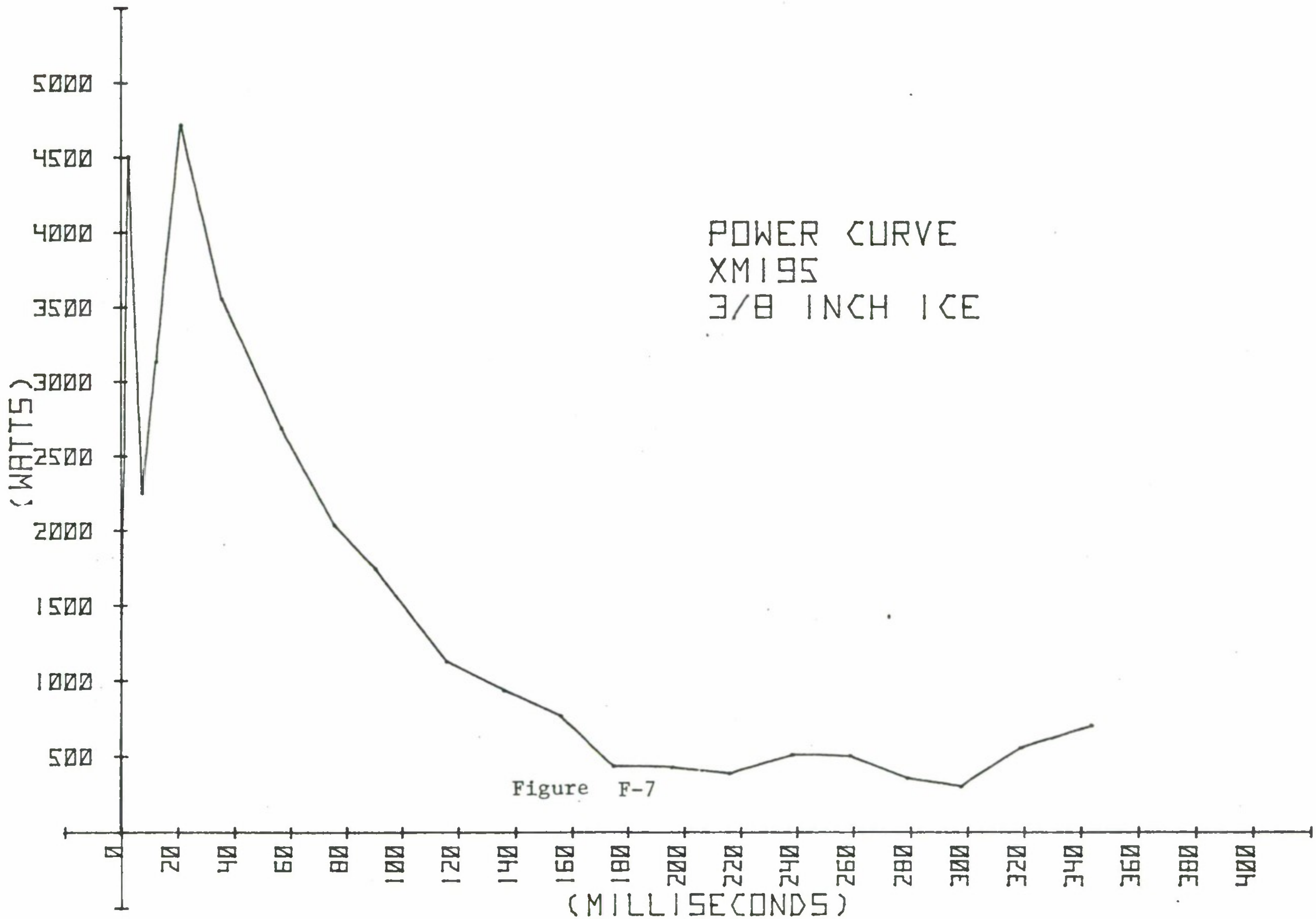
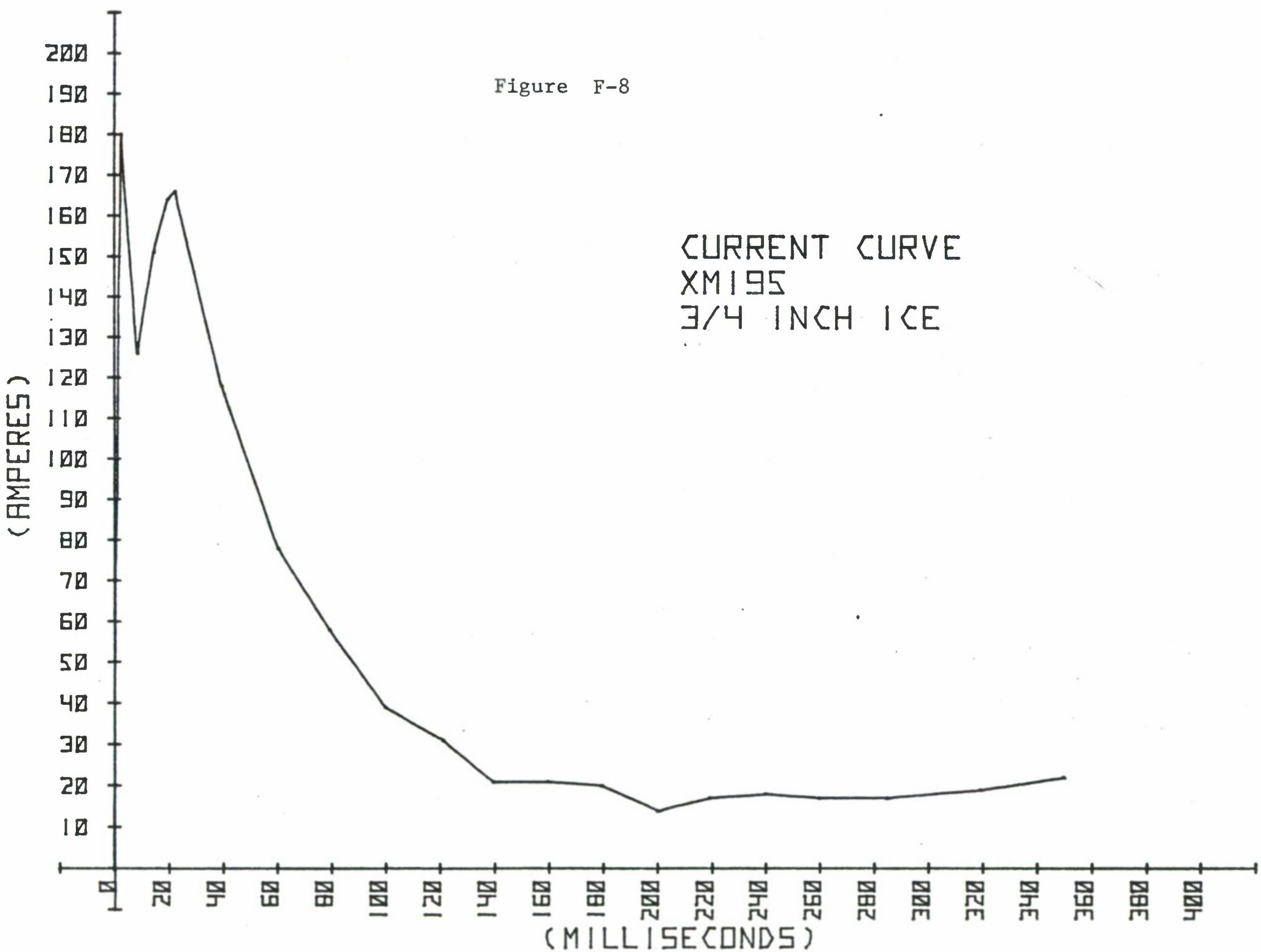

POWER CURVE
XM195
3/8 INCH ICE
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
(WATTS)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

Figure F-7

Figure F-8


CURRENT CURVE
XM195
3/4 INCH ICE
(AMPERES)
(MILLISECONDS)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400

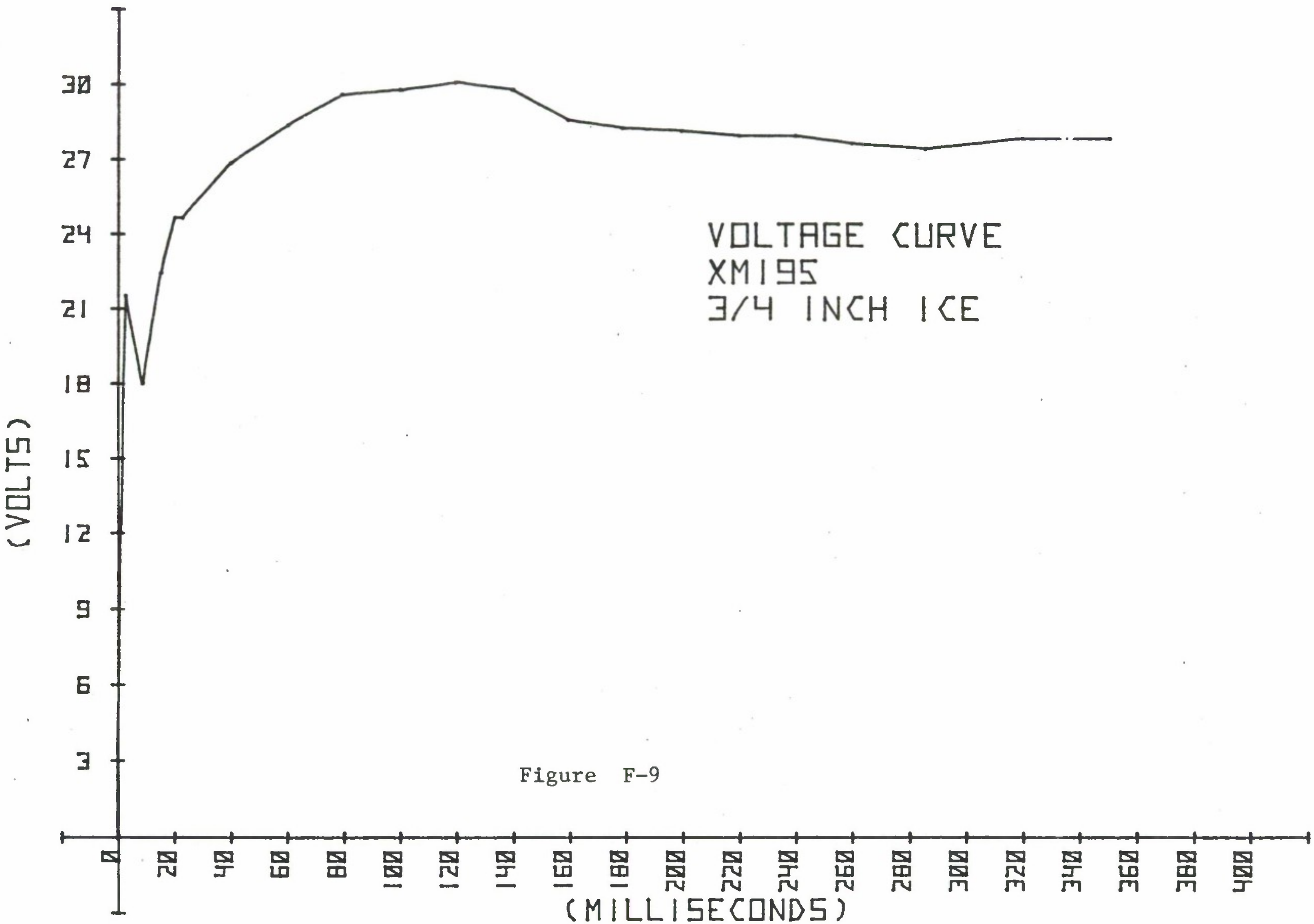
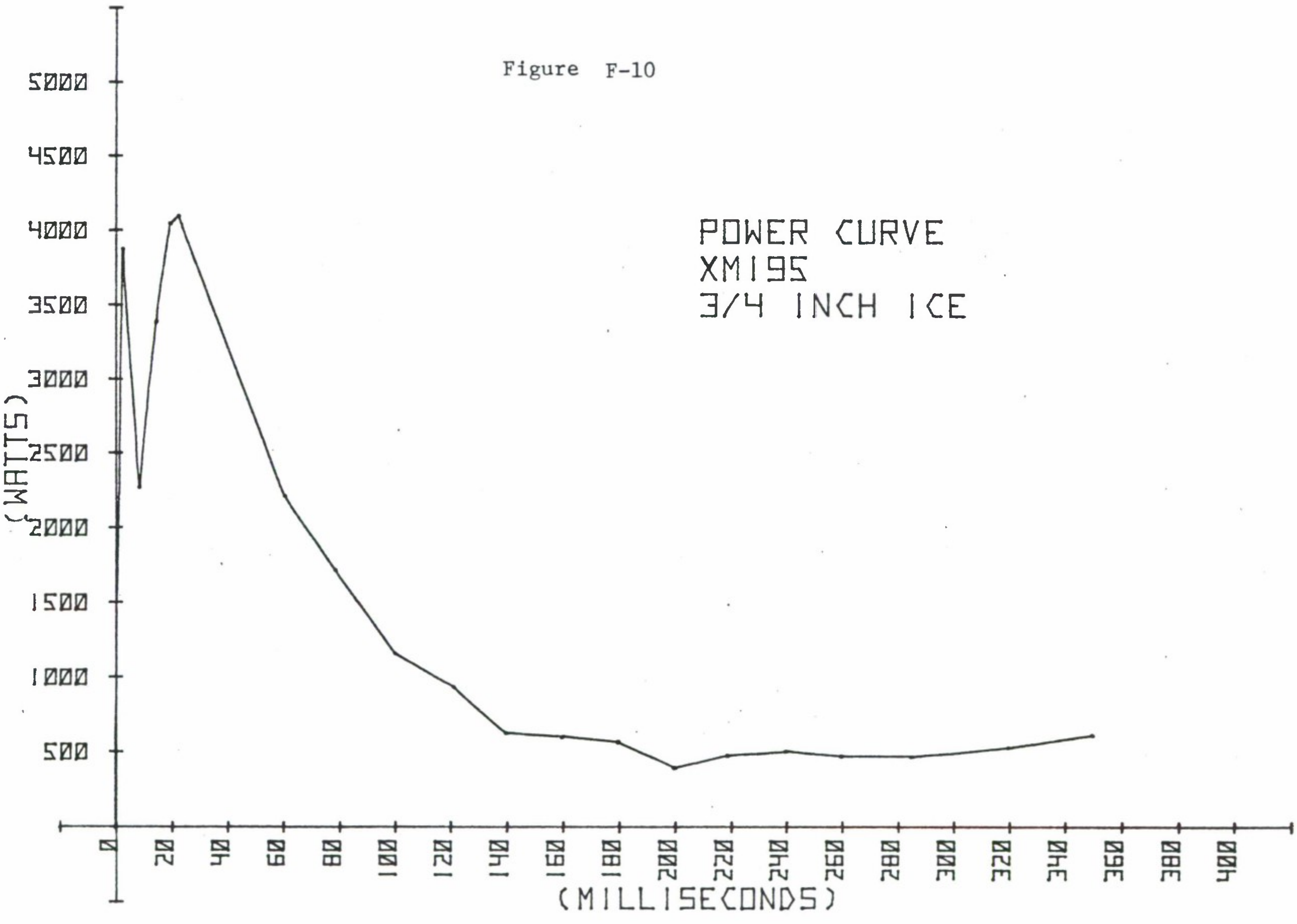

VOLTAGE CURVE
XM195
3/4 INCH ICE
(VOLTS)
30
27
24
21
18
15
12
9
6
3
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

Figure F-9

Figure F-10



POWER CURVE
XM195
3/4 INCH ICE
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
(WATTS)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

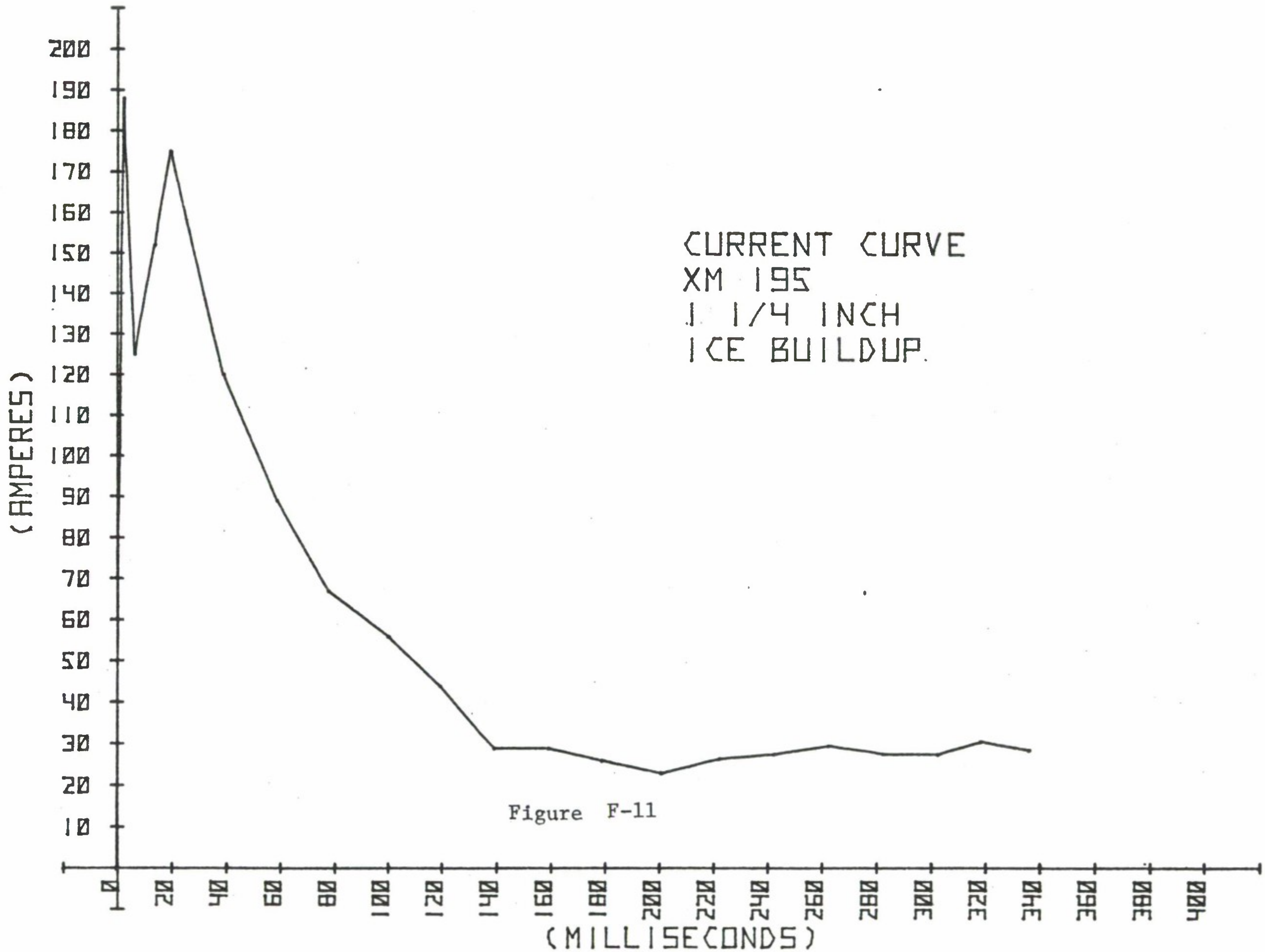
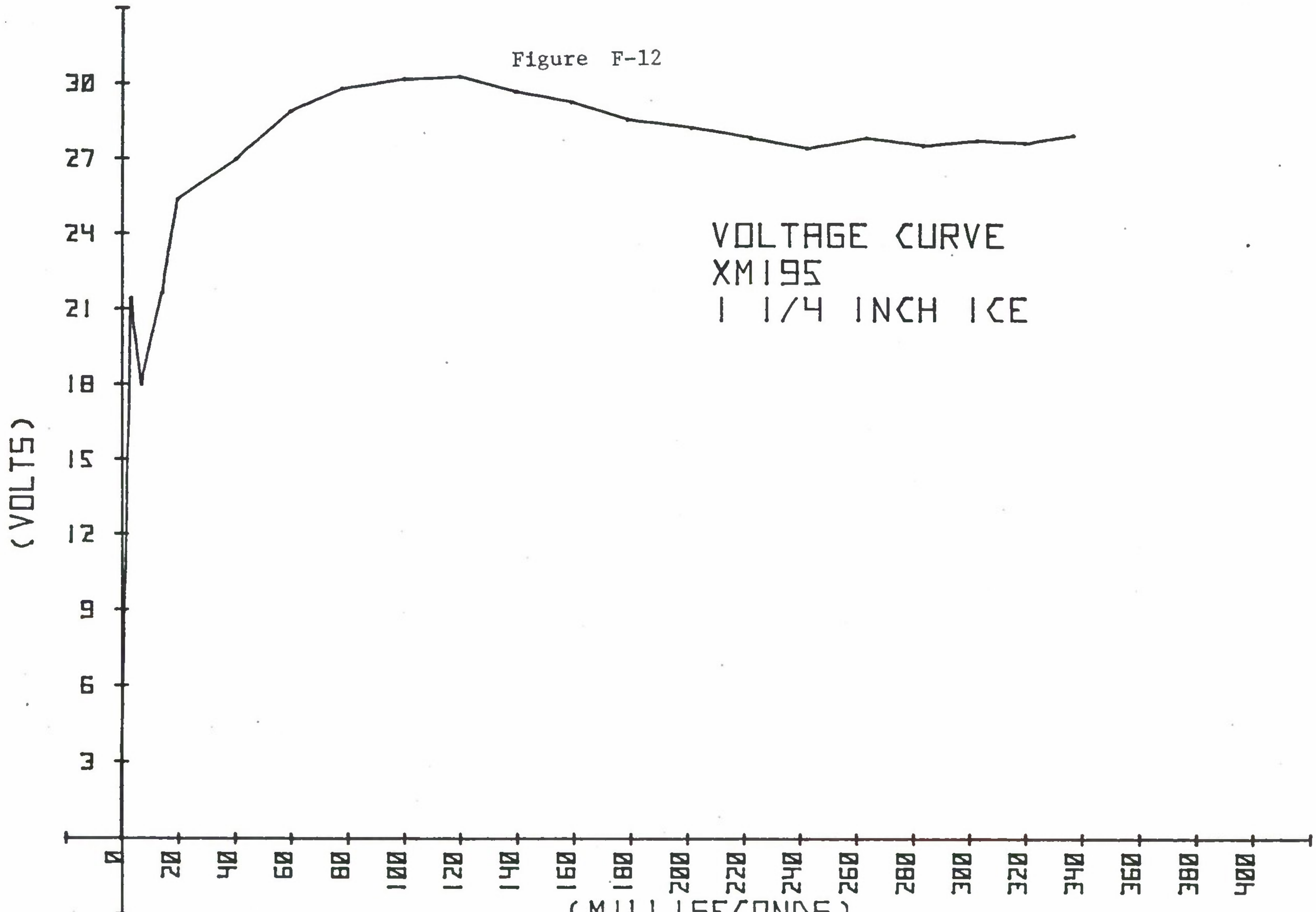

CURRENT CURVE
XM 195
1 1/4 INCH
ICE BUILDUP
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(AMPERES)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

Figure F-11

Figure F-12


VOLTAGE CURVE
XM195
1 1/4 INCH ICE
(VOLTS)
30
27
24
21
18
15
12
9
6
3
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(MILLISECONDS)

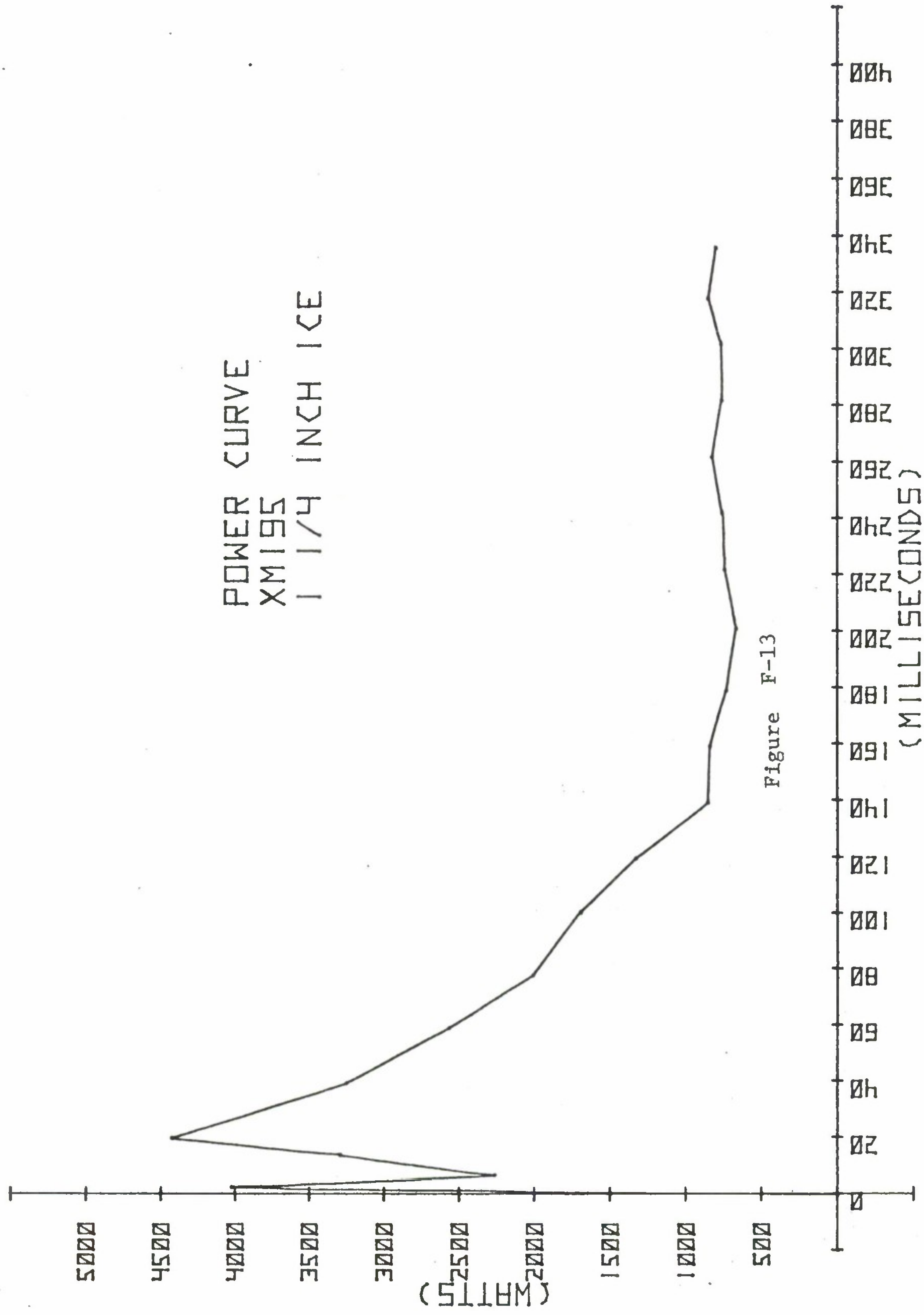

POWER CURVE
XM195
1 1/4 INCH ICE
(MILLISECONDS)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
(WATTS)
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

Figure F-13

APPENDIX G

PHASE VIII DATA

40mm Barrel Test

TABLE G-1

40mm Barrel Plugged With Ice

O.D. Measurements on #2 Barrel

Distance From Muzzle	Measurement Before Firing	Measurement After Firing, 1/2" Ice Plug	Measurement After Firing, 1" Ice Plug	Measurement After Firing, 1 1/2" Ice Plug	Measurement After Firing, 2" Ice Plug
1"	1.798	1.797	1.799	1.805	1.805
2"	1.798	1.797	1.799	1.7995	1.8125
3"	1.7975	1.797	1.799	1.799	1.800
4"	1.796	1.797	1.798	1.798	1.7985

Note: a. Maximum barrel bulge occurred at 1.75 inches from the muzzle. The O.D. measurement at this point was 1.820 inches, which is .020 oversize.

b. Drawing tolerance for O.D. of 40mm barrel is 1.800 - .002.

TABLE G-2

40mm Barrel Plugged With Ice

O.D. Measurements on #1 Barrel

Distance From Muzzle	Measurement Before Firing	Measurement After Firings 1 1/2 in. Ice Plug
1"	1.7965	1.7965
2"	1.7965	1.7965
3"	1.7965	1.7967
4"	1.7960	1.7960

Note: Drawing tolerance for O.D. of 40mm barrel is 1.800 dia -.002.

Blank

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Defense Documentation Center Cameron Station Alexandria, VA 22314	25